MADISON, N.J., PARK BRIDGE.—Designed by H. G. Tyrrell, C.E.

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PAPERS

READ BEFORE THE

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OF THE

SCHOOL OF PRACTICAL SCIENCE

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PREFACE.

The present volume consists of papers read before the Engineering Society of the School of Practical Science during the session 1900-1901.

As in the past, the papers all deal with some of the numerous branches of engineering. Besides being interesting reading, all contain valuable information and will, it is believed, be found useful not only by students, but also by graduates and others engaged in active professional life. The papers on Chemical Wood Pulp and The Conservation of Water for Power Purposes, mark a growing interest in those branches of engineering, upon which the development of this country largely depends.

The Society is to be congratulated upon having secured papers from Mr. H. G. Tyrrell, Mr. C. H. Mitchell, and Mr. A. W. Campbell, each a recognized authority on the subject of which he writes.

The thanks of the Society are due to all who have, by their contributions, or in any other way, materially aided its usefulness.

The present edition consists of 1,500 copies.

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CONTENTS.

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Francis, W. J., '93.
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Johnson, S. M., B.A.Sc., '94.
Johnson, Geo.
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Brown, G. L., O.L.S., '93.
Brown, D. B., O.L.S., '88.
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Clark, J., '00.
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Finch, H. J. W.
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Forester, C., '93.
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Guernsey, F. W., '95.
Guest, W., '00.
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Guy, E., '99.
Hall, G. A.
Hamer, A. T. E., '01.
Harvey, C., '01.
Hanning, G. F., '89.
Henderson, S. E. M., '00.
Hemphill, W., '00.
Henry, J. A., '00.
Henry, J. S., '02.
Herman, E. B., O.L.S., D.L.S., '86.
Hudspeth, W. S.
Innes, W. L., O.L.S., C.E., '90.
Irwin, C. A., '95.
Jones, J. E., '94.
Jackson, F. C., '01.
Johnson, H. A., '00.
Johnson, J. C., '00.
Johnson, J. A., '00.
Laidlaw, J. G., B.A.Sc.,'93.
Laidlaw, A.
Laird, R., O.L.S., '86.
Laing, W. F., '96.
Langley, C. E., '92.
Latham, R., '99.
Lash, N. M., '94.
Lavrock, G. E., '98.
Little, F. J.
Lumbers, W. C., '00.
Marani, V. G., '93.
Matheson, W., '01.
Mace, F. G., '02.
Meadows, W. W., O.L.S., '95.
McArthur, R. E., '00.
McAree, J., O.L.S., D.L.S., B.A.Sc., '82.
McCullough, A. L., O.L.S., '87.
McDougall, A. C., '01.
McDowall, R., O.L.S.,
McFarlane, G. W., O.L.S., '88.
McIntosh, D., '98.

McKenzie, J. R., '00.
McMurchy, J. A., '96.
McMaster, A. T., '01.
McMillan, G., '01.
McMillan, J. G., '00.
McLennan, A. L., '02.
McMichael, C.
McNaughton, F.D., O.L.S., '98.
McVean, H. G., '01.
Milne, C. G., B.A.Sc., '92.
Miller, L. H., '00.
Monds, W., B.A.Sc., '99.
Moore, F. E.
Morris, J. L., O.L.S., C.E.,
Morphy, E. J.
Nicholson, C. J., '94.
Paterson, J., '99.
Perry, F. N.
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Pope, A. S. H., '99.
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Roper, W. P.
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Russell, W., '91.
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Saunders, H. W., '00.
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Smith, R., '98.
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Stull, W. W., O.L.S., B.A.Sc., '97.
Tennant, D. C., '99.
Tennant, W. C., '00.
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Watson, R. B., '93.
Watt, G. H., '99.
Weekes, M. B., B.A.Sc., O.L.S., '97.
Weir, H. M., '00.
Weldon, E. A., '97.
White, A. V., '92.
Whitson, J. F., O.L.S.
Withrow, J. D., '00.
Willson, R. D.
Wickett, T., '89.
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Wilkinson, T. A., '98.
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Withrow, F. D., '00.
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Breslove, J., '02.
Brown, G., '03.
Brown, J. M., '02.
Bryce, R. B., '03.
Burgess, E. L., '03.
Burley, R. J., '03.
Burnham, F. W., '03.
Burwash, N. A., '02.
Campbell, A. R., '02.
Campbell, W., '02.
Challies, J. B., '03.
Charlebois, J. P., '03.
Christie, W., 02.
Connor, H. V., '02.
Corbett, J. T., '03.
Corrigan, T. E., '02.
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Culbert, M. T., '02.
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Gardner, J. C., '03.
Gibson, A. E., '02.
Gillespie, P., '03.
Goodwin, A. C., '02.
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Gordon, J. P., '03.
Gourlay, W. A., '02.
Gray, A., '03.
Green, E. A., '03.
Greenwood, W. K., '03.
Gurney, E. H., '03.
Gzowski, H. N., '03.
Hamilton, J. F., '03.
Hanes, G. S., '03.
Harcourt, F. T., '03.
Hayes, L. J., '03.
Henderson, F. D., '03.
Hendry, M. C., '03.
Henwood, C., '02.
Horton, J. A., '03.
Irving, T. C., Jr., '03.
Jackson, J. G., '03.
Jackson, J. H., '03.
James, E. A., '03.
Johnston, D. M., '02.
Johnston, C. K., '03.
Johnston, H., '03.
Keagey, J. W., '03.
Knight, R. H., '02.
Kernahan, M. G., '03.
Lang, A. G., '02.
Langmuir, F. L., '02.
Larkworthy, W. J., '03.
Latournell, A. J., '03.
Legge, A. H., '03.
McAuslan, H. J., '03.
McBride, A. H., '02.
McCuaig, O. B., '03.
McFarlane, J. A., '03.
McGuire, R. A., '03.
McKay, J. J., '02.
McKay, J. T., '02.
McKellar, J. O., '03.
McKitrick, C. W., '03.

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Marriott, F. G., '03.
Marrs, C. H., '02.
Meader, J. E., '03.
Milden, A. J., '03.
Miller, M. L., '03.
Mills, J. E., '03.
Milne, W. G., '03.
Montgomery, R. H., '03.
Mans, C. A. '05.
Moore, F. A., '02.
Morley, R. W., '02.
Morton, P. E., '03.
Mullins, E. E., '03.
Nash, T. S., '02.
Nevitt, I. H., '03.
Oliver, E. W., '03.
Oliver, J. P., '03.
Pace, J. D., 03.
Pardoe, W. S., '03.
Paris, J., '03.
Patten, B. B., '03.
Philip, H. D., '03.
Plunkett, T. H., '03.
Pinkney, D. H., '03.
Porte, W. B., '03.
Powell, G. G., '02.
Ratz, W. F., '02.
Robertson, D. F., '02.
Robertson, H. D., '02.
Rose, H. G., '03.
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Shipe, H. M., '03.
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Smith, J. H., '03.
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Wanless, A. A., '02.
Weddell, R. G., '03.
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Wilson, N. D., '03.
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OBITUARY NOTICE.

It is with regret that we have here to chronicle the death of one of our undergraduate members, Mr. G. C. McCollum, a student in the Mechanical and Electrical department of the Third Year. Mr. McCollum was the eldest son of ex-Mayor J. R. McCollum, of Welland, Ont., and was twenty-two years of age. He took ill on Thursday, December 20, 1900, and after two weeks of pain died at Toronto General Hospital on January 4. Interment took place with military honors at Welland, on January 7.

Mr. McCollum was a lieutenant in the 44th Welland Regiment. Among his fellows always popular, his decease robbed us of a friend and fellow student.

ENGINEERING SOCIETY

—OF—

The School of Practical Science

TORONTO.

PRESIDENT'S ADDRESS.

GENTLEMEN:—

It affords me much pleasure to welcome you to the opening meeting of our Society.

To those of you who are about to become members, I extend a hearty welcome, while to the older members who have elected me to the highest position in their power I extend my thanks.

You have conferred a great honor upon me in electing me to the office of President, and I sincerely trust that, with the co-operation of the energetic committee which you have elected to assist me, the Engineering Society will continue to prosper as in the past.

It is necessary that each member should do his share in assisting the committee to make this year one of the most successful in the history of the Society.

The objects of the Society are already set forth in the Constitution, copies of which may be obtained from the librarian.

I would like particularly to emphasize the great value to be derived from reading papers at the meetings of our Society. The student members are beginning to take an active interest in this important branch of the School work and those who have read papers in the past will all state that they are exceedingly glad they did so.

Since we recognize no year distinctions, and all papers on engineering subjects are acceptable from our members, I trust that you will carefully consider the many advantages gained and continue to contribute towards the contents of our pamphlet.

Don't let the thought that you are not a senior student keep you from contributing a paper, for it is at our meetings that we have to become more thoroughly acquainted with each other.

As President of the Engineering Society I have to procure the papers to be read at our meetings and published in the pamphlet and I can assure you from my experience this summer that this is no easy task.

There should be no reason why it should be difficult to secure papers from the undergraduate members unless it be that they are not fully aware of the benefits to be derived therefrom.

There are a great many reasons why you should avail yourselves of the opportunity offered to contribute papers and read them at the meetings, and with your permission I will mention a few of these.

The Council of the School, when granting honors, consider the papers read before the Society, so that not only those who listen but also the writer receives much benefit.

One other great advantage of reading papers at our meetings, which is very often overlooked, is that the reader gains considerable confidence in speaking in public. No doubt a number of you will be called upon, at some time in the practice of your profession, to state your views and support them before a meeting of directors of some company or a Town Council. A great deal more weight is attached to a person's opinions if they are given forcibly and without effort, and at our meetings you have a splendid chance to become more proficient in this branch of your profession.

Another advantage gained in compiling a paper is the knack of arranging your material in proper systematic order, which is so essential in the work of the engineer. The notes taken, the extra reading, the concentration of the mind on the subject, and the opinion of your fellow students on your efforts are also of advantage.

After a paper is read at our meetings I would like you to have questions to ask and if possible create some discussion, for in this way many points are brought out which may have been overlooked in the paper.

Last year we were very fortunate in having several of our papers illustrated with lantern slides which were generously supplied by the School. In this respect I might say that a considerable amount of time was expended by some members of the Faculty and the Fellows. In particular I wish to thank Mr. C. H. C. Wright and Mr. A. H. Harkness for their untiring efforts in providing us last year with so many lantern slides, and I trust that this year we may look forward to seeing more of the slides on the screen.

After the papers have been read at our meetings they are filed away until it is time to arrange the material for the pamphlet. They are then submitted to the Editor, who has charge of the publication, and is appointed by the Council of the School, who selects those most suitable for publication in the proceedings of the Society.

Last year 1,500 copies of the pamphlet were printed. Copies of this were sent to all life members of the Society, and all the prominent magazines and colleges in the world. We also make exchanges with a few similar societies in other colleges.

The Engineering Society handles all the draughting paper and laboratory note books used in the School. This year we will purchase our note books direct from the wholesale, but I am sorry to say this is impossible with the draughting paper, as the paper we use is manufactured in Germany. At a meeting of the committee held last May we discussed the advisability of purchasing our paper direct from Germany, but had to give up this idea on account of the lack of funds in the treasury. A great saving in the cost of the paper could be made if we had the necessary money to order our season's stock direct from the manufacturer in May.

This matter has received careful consideration, and the problem of increasing our funds was constantly with me during the past summer. During next summer if each member of our Society both graduate and undergraduate, could obtain an advertisement

to be inserted in our annual pamphlet, the finances of the Society would be placed in such a secure state that we could then buy all our materials direct from the manufacturers. This would mean that our funds would be further increased. There is no reason to reduce the cost of the materials now sold to the students, as they are now below the prices of the retail dealers. This then would mean that we would be able to spend a considerable sum annually in purchasing new and up-to-date books for our library. We could easily spend a few hundred dollars in this work, and it is my opinion that the money could not be spent in a better way. The first object of the Society, as stated in Article 2 of our Constitution, is "the encouragement of original research in the Science of Engineering," and this cannot be encouraged in a more practical way than in providing literature on various scientific subjects for the use of the members of our Society.

I trust that next summer you will avail yourselves of the opportunity thus afforded of helping to place the library of the Engineering Society in a condition that it will be of use to our members.

At our last annual meeting, Mr. Shanks, the retiring President, introduced a new system of voting, which gave such general satisfaction that I feel I cannot conclude without mentioning it. By-law four of our Society states that "a majority of the total number of votes cast shall be necessary for election to any office." When there were over two candidates for any office, under the old system of voting, this would very often make it necessary to hold two or even three elections before one candidate would receive a majority of the votes cast. This caused an annoying delay in the elections and a great deal of unnecessary trouble and work to the scrutineers as well as to the members.

In the new system this was overcome by the voter marking opposite the candidate for whom he wished to vote the figure 1, while opposite his second choice for this office he marked the figure 2, and opposite his third choice the figure 3, and so on. When the number of "first choices" were added, if any candidate had received a majority he was declared elected, but if not then the "second choices" of the lowest candidate were distributed among

the others. If no candidate was then elected the ballots of the lowest candidate were again distributed among the others.

This system was very satisfactory and little more trouble was experienced in counting the ballots than in the ordinary way, and an election was always assured.

Before concluding I would like to make a few remarks about the School. The reputation of the Ontario School of Practical Science, as an engineering college, has been rising for a number of years, until now it is looked upon as being one in which a very thorough knowledge of the foundation of engineering science is obtained. The number of students in attendance has been increasing rapidly each year and it has arrived at the point where very little more accommodation can be afforded. It is crowded in every department and in a year or two if more accommodation is not provided the students will have to go to other colleges to obtain their education.

A large grant from the Government is needed to maintain the high reputation which the School now enjoys, and to accommodate the students who are flocking here annually.

It is with regret that I have to refer to the illness of one of the Past Presidents of our Society, and a member of the Faculty of the School. Mr. Duff has always taken a keen interest in the Engineering Society, but unfortunately will not be able to be with us this year. I am glad to be able to announce that he is very much better and hopes to continue his work in the School next fall. I am sure that it is the wish of every member of the Society that Mr. Duff's health and strength will soon return to him and that he will again be able to continue his lectures and attend the meetings of our Society.

I will conclude my remarks by again thanking you for the honor you have conferred upon me, and will ask that you do all in your power to help the committee make this one of the most successful years in the history of the Society.

F. W. THOROLD.

CHEMICAL WOOD PULP.

J. A. Decew, '96.

In preparing this paper on Chemical Wood Pulp, I have merely attempted a synopsis of the subject, which may convey to those who heretofore have given the subject but little attention, some idea of the methods employed and the chemistry involved in this industry. It is needless to mention that as far as our broad Dominion is concerned, this industry is but in its infancy, for the larger portion of our northern, uninhabited lands are well timbered with spruce, which is one of the best of the paper making woods. Consequently this subject demands more attention than it receives from Canada's Practical Science students, because it has already taken a deep hold upon the financial world, and because our profession above all others, should keep in touch with the industries of the country.

The word pulp is a term which generally may be applied to a number of materials, which are quite variable in character but more or less similar in appearance, therefore if we first classify these in a general way, we shall have a somewhat clearer conception of that special kind, that we are about to discuss. We may divide them into four classes according to quality, namely:

I. Rag Pulp—which is made from cotton, linen or hemp fibres.

II. and III. Wood Pulps—which are of two kinds, chemical and mechanical.

IV. Straw Pulp—which is a chemical product of inferior quality.

As the manufacture of mechanical wood pulp was very ably described in a paper read before this Society last year, the subject matter of this article will deal exclusively with its half-brother of the chemical species, which is in reality another product from the same substance.

Mechanical pulp is simply wood, ground to a fine powder and consists chemically of a combination of celluloses and lignocelluloses. Now if instead of grinding, we treat the wood with a chemical solution, which disintegrates it and dissolves out the lignocelluloses, we then have left what is commonly called chemical pulp, and this consists of those celluloses which have resisted the action of the solvent. As about half of the woody substance is thus removed and destroyed, the remaining product must necessarily be more costly than the ground pulp, but the fibres remaining are white and unbroken and are only comparable with the cheaper product when quality is not required. Mechanical pulp has a very short fibre, little felting power, is quickly discolored in air and light, and is only used as a filling material in news, wrapping, and other papers of a temporary character. Chemical wood pulp, however, makes a good, white, permanent paper, and is the source of most of our writing materials, although it makes neither as strong nor as resistant a paper as do the rag pulps.

The pulps prepared from straw are pronounced oxycelluloses, and have considerably more chemical activity than those prepared from the woods.

There are two distinct methods of preparing the chemical wood pulp, which may be designated as the alkaline and the acid. In the alkaline or soda process the usual method employed is to pack the wood in the form of chips into a horizontal cylindrical, rotating digester, which has a capacity of about three cords.

Here it is digested, with about seven hundred gallons of a six to nine per cent. solution of sodium hydrate, which is heated to high temperatures by means of live steam. The boiling lasts from eight to ten hours, at pressures which may vary from sixty to two hundred and ten pounds per sq. in. The products resulting from this "cook" are a grayish brown pulp and a dark brown liquor, which are dumped into iron washing tanks, and after the liquor is drained off, the pulp is thoroughly washed. But as these wash waters are finally evaporated in order to recover the contained soda, they are used until they become quite concentrated, the pulp being washed continuously with a less concentrated solution until all the alkali is removed. The pulp is now treated with a bleaching solution, which contains twelve to fourteen pounds of bleaching powder

for every hundred pounds of pulp, and this removes the remaining ligneous matter, leaving a pure white cellulose.

The recovery of the soda from the waste liquor is accomplished by evaporation in vacuum pans until it has a density of 40° Baume, when it is burned in a special furnace to remove the organic matter. The remaining ash contains the soda in the form of a carbonate, and when this is heated in tanks with slaked lime. in the proportion of one hundred of soda to sixty of lime, the lime is precipitated as calcuim carbonate and the soda becomes caustic again.

Another method of recovering the soda, which has been lately adopted, consists in heating three parts of ferric oxide with one of soda carbonate, when sodium ferrate is formed. And on heating this with hot water, it decomposes forming sodium hydrate and ferric oxide once more. The liquors of the alkaline process, sometimes contain large quantities of the sulphate or carbonate which are cheaper although weaker in action than the hydrate. In addition to the recovery of the soda from these liquors, a valuable product in the form of acetate, may be obtained from the organic matter of the solution. As perhaps you are aware, one of the standard methods for the manufacture of oxalic acid, is the treatment of wood or sawdust with alkaline hydrates at temperatures ranging from 200° to 250° C.

Now if the heating is prolonged and oxidation is allowed to take place, either from contact with air or oxidizing agents, a large percentage of acetic acid is formed. Therefore if the soda liquor is evaporated and charred at temperatures from 350° to 400° C, the organic matter reacts with the soda to form sodium acetate ($Na\ C_2\ H_4\ O_2, {}_3H_2\ O$). This product comprises about 38 per cent. of the soluble portion of the char, and about 16 per cent. of the residue. With Esparto liquor five to six per cent. of the weight of the original fibre was obtained.

In the soda process poplar is largely used, although maple, cottonwood, white birch and basswood, are also employed. The spruce, pine and hemlock yield a long fibre but are a little more difficult to treat. The main objections to the process are—

1. The high temperatures and pressures required.

2. The formation of dark colored products which are difficult to remove from the pulp.

3. The destructive action that the alkalis have on the celluloses themselves, as the less resistant are attacked and dissolved in the severe treatment required to remove the ligneous portion.

The acid or sulphite process:—

This is the process which is now being most commonly introduced into this country, because it has several important advantages over the alkaline treatments just described. In the first place, the cost in chemicals is less; and a larger yield of fibre is obtained, which is not weakened by the treatment.

And secondly, the paper, which is made from this pulp, is harder and more transparent and durable than that from wood pulps made by other methods.

The treatment consists in digesting the wood at high temperatures with an acid sulphite solution.

The acid radical unites with the products of hydrolysis to form soluble sulphonated derivatives, while the base unites with the acid products of the decomposition. The hydrolitic action is greatly increased by the presence of sulphurous acid, and for this reason, the bi-sulphite ($Na\ H\ SO_3$) solution effects a reduction in less time, and at lower temperatures, than a neutral sulphite solution would.

Now, turning our attention to some of the details of the treatment, we find that the bark and knots and also the resinous matters of the wood, are very slightly acted upon by these sulphite solutions, and must in consequence be carefully removed. Sound knots may be allowed to pass through the digester and be afterwards removed from the pulp by screens. Before very high temperatures are reached it is necesesary that the wood be thoroughly impregnated by the solution, and the absorption is hastened by previously crushing the wood. Dry and green woods, or woods of different species, should not be treated together in the same digester as they will be unequally reduced and leave chips in the pulp.

The first step in the preparation of the sulphite liquor is the formation of sulphur dioxide (SO_2) from the combustion of either

sulphur or its compounds. As this gas must be absorbed by water to form sulphurous acid ($H_2 SO_3$), it is evident that the less it is diluted with other gases the more complete will be its absorption. Therefore the sulphur is burned in specially constructed furnaces with the object of obtaining a complete combustion with the smallest possible draught. If the combustion of the sulphur is incomplete, a part of it sublimes and re-acts with the sulphur dioxide to form thiosulphuric acid ($H_2 S_2 O_3$) which in turn forms thiosulphates. These will decompose on boiling, and precipitate the sulphur into the pulp, which, being practically insoluble, it is impossible to remove. When this sulphur becomes oxidized to sulphuric acid it is very injurious to the paper making machinery as well as the pulp.

When pyrites is used in the production of sulphur dioxide more complicated burners are used, and additional care is taken to avoid overheating, for slags are easily formed which impede the draught and are difficult to remove. Blowers or exhaust fans are used to improve the draught through the furnace, and these cause a lot of fine dust to be carried over with the burned gases. This dust never reaches the pulp however, as the gases pass directly from the furnace into a dust chamber where it settles before the gases enter the cooler.

From the fact that one volume of water at zero centigrade will absorb sixty-nine volumes of sulphur inoxide; and at forty degrees will absorb but seventeen volumes, it is evident that the temperature of both gases and liquor will be kept down as much as possible during absorption. In practice the temperature of the cooler varies from ten to fifteen degrees. The absorption apparatus are of two kinds, namely, that in which the gas is absorbed by water holding the base in suspension or solution; and that in which the gas and water react together upon lumps of the carbonate of the base. The latter method, which is the older and simpler, consists of a high shaft or tower packed with limestone or dolomite, which is covered by a thin film of water that enters from above. The gases enter the base of the tower under pressure sufficient to force them up through the limestone and out at the top. The sulphur dioxide meeting the moist limestone, reacts with it, forming at first sulphurous acid ($H_2 SO_3$), and then calcium sulphite

($Ca\ SO_3$), while this insoluble product unites with more sulphur dioxide to form calcium bi-sulphite [$Ca\ H_2\ (SO_3)_2$], which being soluble is washed out by the descending water. The former or tank apparatus is the one generally used in this country, and consists of a series of tanks filled with water which holds the carbonate in solution or suspension.

In this case the chemical reaction is practically the same as just described, for as the sulphur dioxide is absorbed, the insoluble calcium sulphite is precipitated, but becomes redissolved as it reacts with more sulphur dioxide to form the bi-sulphite [$Ca\ H_2\ (SO_3)_2$]. In practice more or less of the insoluble sulphate ($Ca\ SO_4$) is formed by oxidization, which is allowed to settle and then the liquor is drawn off and stored in air tight, lead lined tanks, until it is required for use.

The real process of pulp making begins when the chips and liquor are brought together in the digesters, which vary in size, and may be either upright or rotary. But the great difficulty in making digesters for this process, is to obtain a suitable lining which will protect the iron plate from the corrosive action of the sulphurous acid. The usage in the past has been generally in favor of lead linings, as they are but slighted acted upon by the acid, and are further protected by the coating of lead sulphate which forms. The objection to the use of lead, to overcome which many devices have been tried, is the fact that it has about double the co-efficient of expansion of iron, so that in alternate heating and cooling, it buckles and draws to such an extent as to soon necessitate repairs.

Bronze linings have been used with some success, and boiler scales in the form of sulphite of lime or silicates of iron and calcium have worked very well.

But the digester lining that takes the precedence and which is now being rapidly introduced, is merely a layer of Portland cement of about four inches in thickness, and this may be applied to the boiler directly or first made into slabs and then fitted in. At first it is more or less porous, but the interstices are soon filled by a deposit of sulphate and sulphite of lime which render it quite impervious. The cheapness of the application and repair of this lining will recommend its general adoption.

In a digester containing two cords of chips, about twenty-five hundred gallons of a three and one-half per cent. liquor is used. The temperature is raised slowly until after the wood has become saturated with the liquor, and then a steam pressure of sixty-five to eighty-five pounds is turned on, which is equivalent to a temperature of one hundred and fifty-five to one hundred and sixty-five degrees centigrade. At these high temperatures the bisulphite is decomposed into sulphurous acid, and the normal sulphite, which being insoluble is deposited in the pipes or pulp. The sulphurous acid gas forms a hydrostatic pressure, which, added to that of the steam for the given temperature, gives the total pressure in the boiler.

Thus the pressure may be considerably increased, by the formation of this gas, without an equivalent rise in temperature. On account of the greater convenience the digesters are heated by means of live steam, which, by condensing in the pulp, is continually diluting the solution, but by employing a non-conducting jacket very little difficulty is experienced in practice, especially when cement linings are used.

At the end of the cook the gas is nearly all blown off and then the pulp is blown out under a pressure of about thirty pounds. This saves time in handling and the trouble of beating. It must now be thoroughly washed to remove any of the precipitated sulphite, especially when bleaching is to follow, for the sulphite is a strong antichlor itself, as it takes up the free oxygen formed by the action of the chlorine.

The pulp is never a pure, permanent white until after the ligneous and coloring matters remaining, have been broken up and removed by the action of a bleaching agent. The true bleaching action is purely an oxidization, which breaks up the coloring matters into simple colorless oxidized derivatives. With bleaching powder ($Ca\,O\,Cl_2$) the chlorine unites with the hydrogen of the water and this action liberates the oxygen which does the work. Pure oxygen, ozone or hydrogen peroxide, may also be used with equal effect. On the other hand the bleaching action of sulphurous acid is of a quite different character, for it combines with the coloring matters to form colorless compounds, which are easily reduced with a return of the color when the acid is neutralized.

You will naturally wonder what becomes of the waste liquor in this process, and this is one of the problems that has been left for this century to decide. In some places the gas is recovered but the general practice is to dump the liquors into the nearest pond or stream to get rid of them. This not only means a loss of half the woody structure and the gas in solution, but the effect of these liquors in fishing streams is remarkable. The sulphurous acid being a reducing agent, combines with the free oxygen in the water, and the organic paste in the solution forms a coating over the gills of the fish; therefore the fish have left no atmosphere and could not breath it if they had. If the waste liquor is evaporated the residue has no fuel value, therefore we must look in other directions for methods of conversion into valuable bi-products. All that is known concerning the chemical composition of these liquors, is that they are sulphonates containg the OCH_3 group. Future research may result in the manufacture of either glucose, alcohol, oxalic or acetic acid, from this organic residue.

Resinous woods are not very suitable for pulp making, as the resins are insoluble in hot bi-sulphite solutions, and although they are dissolved by the alkaline solvents, every hundred parts of resin will neutralize eighteen parts of the alkali.

Woods such as chestnut, which contain tannin, should not be treated by the sulphite process, as the tannic acid would act as an oxidizing agent, converting the sulphurous into sulphuric acid. Spruce and poplar are used almost exclusively in the sulphite process.

If a compound cellulose such as wood is treated with water at a high temperature, a hydrolitic action takes place with the partial isolation of cellulose and the formation of soluble compounds with an acid reaction. All of the commercial methods of isolating cellulose depend upon this hydrolitic action. The soda process is a basic hydrolysis, and the sulphite process is an acid hydrolysis, although the chemical reactions that actually take place in the cellulose molecule, are yet but a matter of conjecture. The emperical composition of cellulose is the same as starch ($C_6 H_{10} O_5$), but they differ remarkably in resistance to hydrolysis and in many other ways. This indicates a difference in the linking of the

unit groups, and in the reactivites of the OH groups, which in cellulose exercise a purely alcoholic function. The investigations of Cross and Bevan indicate that the cellulose formula is $C_6 H_6 O (O H)_4$, or some multiple of this which is in a more or less hydrated condition, according as it is more or less resistant to hydrolitic action. All those celluloses that are eaten and digested by the herbivora are extremely hydrated forms, and they become more resistant to external agencies as the water of hydration is removed. This fact is well exemplified in the discriminating way that fodder eating animals usually select their foods.

THE BONDING OF BROKEN STONE ROADS.

A. W. Campbell, C.E.

Before entering upon the subject which I have brought before you today, in the title of this paper, it will be well to review briefly the construction of a broken stone road. In general, the first step in the construction of a broken stone road of modern design is to prepare the natural sub-soil, on which the stone road surface is to rest, so as to make of it a firm and strong foundation. This treatment of the sub-soil for the most part, is a matter of grading and under drainage, especially the latter. It is the natural soil which must bear up the weight of traffic, and a wet, yielding foundation is not a suitable support, when bridged over with any form of paving material. With the exception of light, and partly decayed vegetable mould, nearly all soils, when kept dry by under-drainage, are sufficiently strong to support the heaviest traffic, but when saturated with water, every soil is weakened. Natural drainage is frequently sufficient, so that artificial under-drainage, usually of common porous tile, is not always necessary. The kind of soil, whether clay, gravel, sand, loam, and the facilities and need for drainage will indicate the means to be adapted.

An excavation is made to receive the stone; if a town or city street, curbing is placed along the sides; the sub-soil is thoroughly consolidated with a roller, and upon this is placed the stone, broken into fragments varying in size from stone dust and screenings to such as will pass through a 2½ inch ring. If the traffic is great, or if the soil is of a kind particularly difficult of drainage, as for example what is described as an "oily clay," a Telford foundation is particularly useful. A Telford foundation is composed of stones of varying sizes, not exceeding ten inches in length, six inches in breadth on the broadest side, nor four inches in thickness on the narrow side. These stones are placed lengthwise across the road, breaking joints as much as possible; the interstices are filled with stone chips, all projecting points are broken off, and the whole structure is wedged, consolidated and made as firm as possible. As a cheaper means, the stones are commonly placed flat on the road.

closely together. The surfacing metal is then placed on this "pitched" foundation, in the usual way, usually to a depth of at least six inches, and for heavy traffic may have a depth of ten or twelve inches.

In placing this broken stone in the roadway it is spread in layers of about four inches in thickness, and a steam roller passed over each layer to consolidate them. The road surface should serve two ends. It should present a smooth, hard surface to traffic; and it should be impervious to moisture, so that rain falling upon it will not pass into, and soften the earth on which it rests. That is to say, it should answer the purpose of both a floor and a roof. These objects are attained by making the surface of the roadway higher at the centre than at the sides, so as to shed the water to the side gutters, and by compressing and compacting the material of which the road is composed. This compressing of the roadbed is usually performed either by traffic or by means of a heavy roller, aided by intermixing with the stone, certain fine stuff, screenings (the chips and stone dust created by crushing), sand, loam, street scrapings and even clay.

The use of a binding materal in the construction of broken stone roads, is a matter which has been the subject of much discussion, with a corresponding diversity of opinion. The kind of material, the amount, the method of using, forms an interesting chapter in the history of road-making, and it is to this, together with the use of a roller, to which the title of this paper draws attention.

The use of the roller, and therefore the bonding of the road, begins with the earth sub-soil. The roller used on the natural soil will serve two purposes; it will find the weak spots in the sub-soil; will consolidate it, and assist in providing a firm foundation. Unless the sub-soil is rolled, uneven settlement is likely to take place after the road is completed, creating depressions in the road surface, a matter obviously to be avoided. By rolling it, on the other hand, wherever there is a quantity of loose soil, created in drainage excavation, in filling, or is weak because of its composition, it will be forced down beyond the possibility of settlement. The earth sub-soil too, if given a crown similar to the finished surface

of the road, and its surface thoroughly hardened, will have, itself, a tendency to assist in the drainage of the road by throwing off such water as may percolate through from above.

When this is consolidated, it will form a hard and firm base, upon which to roll and consolidate the succeeding layers of stone. If the stone is merely placed upon an unconsolidated sub-soil, the result can readily be imagined; the stones are forced by rolling into the sub-soil, and the earth is worked up among the stones. The subsequent rolling is less effective, and whatever beneficial drainage would result from a smooth sub-soil surface is lost.

The sub-soil, then, having been thoroughly rolled, a Telford or other "pitched" foundation, if required, may be laid, and this also rolled. Upon this, the broken stone is placed. It should be spread in layers, and each layer thoroughly rolled. The thickness of the layers, as spread over the road for rolling, will vary in accordance with many circumstances, the weight of roller used, the size and hardness of the broken stone, the ultimate thickness of the road bed, etc. Six inches loose should be a maxim thickness, while three or four inches is preferable. Where the stone is graded, as it should be, into different sizes, each size of stone should be placed on the road and rolled separately. As an instance of what might be done, take the case of a layer of stone to be six inches in depth when consolidated, it would be most practicable to roll down two layers of four inches thickness, loose, which, when compacted will make about the required depth. The greater the depth of loose material under the roller, the less perfect will the consolidation be, and there is the possibility of its being crowded into heaps over which the roller cannot pass.

The effect of the roller on the stone mass is to wedge the stones against one another, interlocking them, and giving them a mechanical clasp, one of the other, which is not readily disturbed by traffic. The roller is now used in preference to the old-time method of merely allowing traffic to do this work of consolidation, and is absolutely necessary to the best workmanship. Without the roller, the sub-soil is much disturbed by the pressure of narrow tires and by horses hoofs, before the surface protection becomes a

protection, an effect much increased by wet weather. Before consolidation is attained under traffic, the sharp angles of the stones, which materially aid in procuring a durable bond, will be worn off. Without a roller, too, the stone cannot, with the best results, be placed in the roadbed in graded courses, the largest stones in the bottom and the finest on top, for traffic over the loose material will intermix them, allowing the large stones to work to the top.

The objection to large stones, of say 2½ inches in diameter, at the surface of the road, is that they do not assume so firm a bearing, as will smaller stones; they are more readily disturbed by pressure at one corner or at one side and are apt to be found rolling loosely under the wheels, and feet of the horses, nor do the different sized stones, if at the surface, wear evenly, the smaller wearing more quickly than the larger, so that a roughened surface results. On the other hand, it is urged that the finer stones intermixed with the larger, will lessen the percentage of voids in the mass. While this is no doubt true, yet the presence of large stones at the surface becomes very objectionable, and it is probable that the voids in the mass may be sufficiently filled by other means.

Rollers may be operated by horses or by steam power. Horse rollers usually weigh four or five tons, but may be weighted to six or eight tons. Steam rollers for broken stone roads weigh from eight to twenty tons. The objection to a heavy roller is that it cannot be used in soft material, as it bunches the earth or stone, creating mounds over which the roller cannot pass. An excessively heavy roller crushes the stone into position, breaks off the sharp angles, instead of working the stones gradually into a wedged condition. The heaviest roller, too, is apt to injure gas and water mains if at shallow depths, and they strain bridges, culverts and crossings. In a number of English cities, London among these, eight ton rollers are employed to prevent injury to city gas mains. Very light rollers, however, do not do the work of consolidation so quickly or perfectly as will one of moderate weight. Ten, twelve and fifteen tons will render the best service, twelve being a good standard. Where under-ground pipes, culverts, etc., are not a consideration, and two rollers are obtainable, a light roller for the loose material, and a heavy roller to complete the consolidation will

give the best results. Horse rollers are not desirable, as they are too light, and the efforts of the horses to move them disturb the loose metal very much. This last objection would not be so great if the horses were always well-trained, and the drivers understood their work; but, particularly in starting the roller, or on grades, the horses are not apt to pull together and their clumsy efforts before they get under way do very noticeable injury. While even in England, road rollers are not in use by all corporations, there remains no doubt as to their being essential to the most successful and economical results.

The percentage of voids in loose crushed stone varies according to the size of the stone, and whether or not the stone is screened into grades of equal size. The smaller the stones the greater the percentage of voids, and if graded the percentage of voids is also greater than where the stones are of unequal dimensions. For various conditions the percentage of voids has been found by experiment to range from 41% to 51%. For loose graded stones of 2½ inches diameter, the voids may be accepted as about one-half. The effect of rolling is to reduce the voids about one-half, leaving the per cent. of voids about one-third of the consolidated roadbed.

It is evident that to secure an impervious road covering which will protect the sub-soil from moisture, this considerable percentage of voids must be filled. "Nature abhors a vacuum," and unless the right material is used to fill the vacuum, the wrong material will be apt to force its way in. Without some material to occupy the space, the earth from below and the dirt from above will ultimately be forced and absorbed into it.

The materials commonly used for that purpose have been previously enumerated, stone screenings, sand, gravel, clay, loam, and street sweepings; but of these the two first are those most commonly employed. The manner of applying them is in general the same. A light coating of the binding material is spread over each layer of broken stone, is sometimes harrowed in, and the roller is then used.

The use of these materials as a "filler" is neglected in the name now applied to them, "binding materials." The real reason

for their use at all, by most engineers, is that they assist in producing a quick consolidation, less rolling being required than when they are omitted, of which the use of such materials as clay, loam and street scrapings is in evidence.

Of these materials as a "binder" the only one which receives the full approbation of the most reliable engineers, is screenings—the fine chips and dust produced in crushing. There is a quality possessed by this material which is exhibited by no other, that of cementing and re-cementing. This is a matter which of recent years has attracted much attention, and the quality of a stone as a road material is not to be judged merely by its hardness and toughness; but also by the cementing qualities of the dust. This dust is an important factor, it is supplied to the road in the first instance, it is constantly being created by the use of the road. It is in this way that limestone holds its place as a good road metal, for which it is apt to be soft. The dust possesses splendid cementing qualities making one of the most impermeable road surfaces. The dust of trap rock, ranks exceedingly well in this regard, which supplementing the hardness and toughness of the stone, makes it the most satisfactory for road purposes. On the other hand, granite, while hard and tough is lacking in cementing power, and is not as satisfactory as might be anticipated. Quartzite also is an instance of a poor cementing stone, and sandstone, unless bituminous, is also defective in this regard. So important is this quality considered by the Massachusetts Highway Commission, that they regularly test the stone used on the State roads for the cementing power of the stone dust, together with tests for absorption, impact and abrasion.

The use of foreign material, that is, all except stone dust, was strongly condemned by Mr. McAdam; in France, where road-making is more exactly studied than elsewhere, it is universally condemned, and the best practice of all countries forbids it. Clay, loam, and even sand, it is recognized, can only be used at the expense of the durability of the road. They assist in producing an apparently good roadbed with the least amount of rolling, but the bond is temporary, very subject to changes of weather, particularly wet weather, and alternate freezing and thawing, matters which

have to be carefully guarded against in this climate. When foreign "binders" are used, there is lacking in the road the firm mechanical inter-locking which continued rolling will produce; they lack the binding properties of stone dust; most of them are very absorbative of moisture, are even slippery, so that the stones are readily displaced by traffic, and a roughened and rutted surface ensues. In the time of a prolonged draught, foreign binding materials are most ready to contract, so that there is a tendency for the road to unravel.

The conclusion, therefore, which we come to is, that for bonding and inter-locking a broken stone road, first dependence should be placed upon the roller. For what it will not do in filling the voids, the dust and chips created in crushing the stone should be employed, bringing with them an added cementing value; foreign material, such as sand, clay or loam, can be included in the roadbed only at the expense of ultimate durability.

EXPLORING NEW ONTARIO.

ALEXANDER H. SMITH.

During the last session of the Ontario Legislature, a scheme was evolved for the exploration of unsurveyed lands north of the Canada Pacific Railway line, for information as regards the soil, timber, and mineral resources. For the purpose a sum of $40,000 was voted; and during the summer ten parties were organized to do this work. Eight of these were simply exploratory parties, the other two ran base lines as well as explored.

The exploration parties consisted of, in each case, a land surveyor, a timber and land estimator, a geologist, a cook, and men to act as guides and canoemen. The surveyor controlled and directed the work of the whole party, he also made a track survey of the principal rivers and lakes in the region, took notes on the meteorological phenomena and acquired information as to the soil and forest growth, the fish, fauna and flora.

The duties of the timber and land estimator were to note the kinds of forest trees and their dimensions, estimating their extent and the quantity in feet B. M. or in cords as the case might be. He also had to note how such timber could be transported, and if the streams were capable of floating such timber. As regards the land: he had to note the soil whether sandy, clayey, etc., and its capacity for growing crops, and of what kind.

The geologist took cognizance of the general topography of the country, its rivers, lakes, hills, and valleys, the rock formations, whether Laurentian, Huronian, or of later age; mapping their strike (if any), direction of contacts, and length and breadth of formation, where such could be made. Of necessity his chief work was to discover if the formations yielded any economic minerals, and to determine the kind and richness of such. Another branch of his work was to examine the fauna and flora and the Indian occupation.

The three officers of each party were required to keep careful field notes as well as diaries, and their whole object was to collect as much useful information as possible on the country that came under their notice. The region was so mapped out that the whole of it might be examined in one season, each party having a distinct territory to work in.

Early in June I was informed by Mr. Archibald Blue, Director of the Bureau of Mines, that I had been appointed Geologist to exploration party No. 8. This party had the region immediately to the west of Lake Nepigon, and the Nepigon river to Dog lake, up Gull river and the country around Black Sturgeon lake. David Beatty, O.L.S., of Parry Sound, was in charge, while John Piche, of Copper Cliff, was to act as timber and land estimator. Towards the end of June our party met at Collingwood and proceeded to Port Arthur by boat thence east to Nepigon Station on the C.P.R., where we started our work. During the greater part of the season our party consisted only of eight men, two of them being University of Toronto men who were anxious to see this grand country and try their prentice hands—and heads—at the noble arts of paddling, and "totting" supplies across rough trails and portages.

Our outfit consisted of four canoes, two Peterboroughs and two small barks; four tents and two tons of provisions, the estimate that was made in regard to the latter, being a pound and a half each of flour and pork a man per day. Of course other supplies were taken, such as sugar, raisins, rice, etc., this amount of provisions was calculated to last us about five months; only half the supplies were taken up to Lake Nepigon, where we started our work, the other half being stored at Nepigon Station.

Owing to a hitch in the forwarding of our supplies to Nepigon Station, our party was unable to proceed up the river for a number of days, so I accepted the kind invitation of Mr. Walter Beatty, M.P.P., to accompany him on a trip to the east side of Lake Nepigon to look at some mineral deposits he had seen there years before. By this I escaped the disagreeable wait at Nepigon. Mr. Beatty also arranged to send me across Lake Nepigon so that I could join my party at Gull river.

On the way up the river, we were fortunate enough to catch a number of the large speckled trout that make this region the most wonderful trout fishing place in the world.

Mr. Beatty was rewarded in his search by finding a large deposit of hematite, which I measured in a number of places and found to be over a hundred feet wide. The iron is banded with jasper and appears to be wholly in the Huronian formation, the lead running for a number of miles east and west. Since Mr. Beatty's discovery, there has been a regular stampede of local men into the region and numerous claims have been taken up, and other ranges parallel to it discovered. While on the east side of Lake Nepigon I saw what is known as the Shuniah silver mine, near Poplar Lodge. This deposit appears to be a green quartzite, containing native silver and galena. During my stay on the east shore I managed to get about sixty miles inland, and was thus able to see that the country was well wooded with good spruce.

I should not be at all surprised if valuable mines are opened up in this region when means for transportation are found. I believe there is a charter for an electric railway into this country, the power for operating it to be procured from the Nepigon river. The Sturgeon river, the largest flowing into Lake Nepigon, is quite close to the iron range, and is capable of producing a large amount of power when required.

Leaving Poplar Lodge, H. B. Co. post, on the east side, and after an all day and night's trip with two Indians across Lake Nepigon I reached Nepigon House, the Hudson's Bay's chief post on this lake. This trip shows how large a lake this is, as the Indians kept steadily at work, only resting now and again to eat. The lake in fact is about 80 miles long by fifty broad; the water is beautifully clear and very deep, and simply teems with speckled and lake trout, white fish, pickerel, pike and sturgeon. From Nepigon House another half day's trip brought me to Gull river, where I joined my party.

Our method of exploring was this; the surveyor made a track survey of all watercourses taken; this he did with a prismatic compass and a Rochon micrometer, generally using a ten link target. The disks—which were celluloid—were one foot in diameter, one

red and the other white. For short distances a small disk was attached to the centre of the pole, thus giving a five link base: for very short distances one disk itself answered. With this target, distances of a mile could be estimated with considerable accuracy, and a traverse of a lake or river could be made very rapidly, often seven or eight miles of crooked river being surveyed in one day. The track survey was checked by taking frequent observations for latitude and also for magnetic variations, in this way a fairly accurate map of the country could be obtained. This work generally employed five men, two for the disk canoe and two for the surveyor, supplies were moved in the canoes used for the traverse.

The timber estimator and myself made numerous explorations to the right and left of the track survey at distances of about five miles apart, walking inland five or six miles and very often remaining away from the camp all night. In these explorations our method was to take a straight compass line and time ourselves: we estimated that our progress was one mile an hour in a straight line: a good day's work being ten or twelve miles: now and again we used to take our blankets and provisions and walk inland all day, camping for the night, and returning the next day. In this way a good idea of the country on each side of the water route was obtained.

Any side water route that we had not time to survey would be explored by either the timber estimator or myself, taking for this purpose an Indian as guide. Distances were estimated either by eye, or timing, and compass readings taken, outlines of lakes and rivers being carefully mapped in the field book. For the purpese of these explorations our party was supplied with a Kay Taffrail log, an instrument very much like a trolling spoon in shape, tied to a long line. This spoon while revolving set in motion a register which registered the miles travelled. Unfortunately the first day I used it, a large pike mistook it for something good to eat and proceeded to bend the flanges of the spoon, and as the gauge for straightening them had not been sent, the instrument was practically useless. Another drawback to the instrument was the indicator, which refused to work after registering ten miles.

These canoe explorations sometimes led us long distances inland, taking three or four days, and often a week, to com-

plete; and it was often very difficult to calculate the exact amount of provisions to carry with one. Of course every unnecessary thing was left behind, and only the absolute necessities taken. Unfortunately I was unable to speak Indian very well, so when I left the main party I had to take two Indians, as I found out that with only one I was always in danger of having to turn back, as he would get very lonely and be afraid to venture farther inland, with two Indians they would keep each other company, and as long as they had enough to eat they seemed quite happy.

The equipment for three men on one of these explorations, constisted of pork, flour and tea, three tea tins, a pail, frying pan, blankets, and a canvas tarpaulin for a tent. All through the summer we never used a tent except when with the main party; the bulkiest part of our equipment would be, of course, our blankets. We generally depended on shooting enough partridge and ducks to help out the other provisions, and with these additions we were always able to cut down our supply of pork and flour. Some surprisingly accurate work was done with only estimated distances; three explorations I made between two fixed points showed an error of only a couple of miles when the exploration was plotted, although the distance travelled was very long, in one case about ninety miles. Two common errors can exist, first an inaccurate compass reading; and second a wrong estimation of the distance, but I found out that these errors had a happy faculty of compensating each other. In this work all portages were paced, allowing about twenty-five paces to the chain. It must not be thought that these side explorations were in any way correct, but they will be of some value to the further opening up of this country, as they will show fairly accurately a large number of canoe routes, the number and length of portages, and the general direction taken by the route.

Much valuable information was thus procured as regards timber, land, and the geological formations.

In calculating the amount of timber in the region explored, the method the timber estimator used was to pace off an average acre, estimate the average diameter of the trees and counting them, this was rather a tedious process, but then a fairly accurate determination of the timber in the region was procured. The number

of each variety of tree was noted, and their suitability for either lumber, pulp wood or railroad ties. The timber consisted of spruce, jack pine, poplar, white birch, tamarac, balsam, and occasional scattered groves of red and white pine and white cedar.

The character of the soil was noted by the exposures seen under the roots of freshly fallen trees, or by the exposures along the banks of small streams.

The areas and depths of any peat deposits were noted, an idea of the depth being obtained by means of a pole.

Outside the general work of exploring and mapping out the country, the geologist was required to get a general idea of the topography of the region, the main and subsidiary water sheds, the heights of mountains and hills, which he estimated by means of an aneroid, two of which were carried by the party.

Four series of rocks were met with in the region explored by party No. 8. The Laurentian, Huronian, Keweenawan and Animikie. Roughly mapping these, the Laurentian area, which was gneiss as a rule, is around Dog lake. Keweenawan formation immediately to the west of Lake Nepigon and Nepigon river, the Animikie along Nepigon bay and west along Lake Superior, while numerous areas of Huronian rocks were noted at the headwaters of the Gull river. The rocks of this latter series being schists and porphyroids.

Dr. Robert Bell of the Canadian Geological Survey calls the Keweenawan series of rocks the Nepigon series. This formation consists of the following rocks in ascending order, white grits, red and white sandstones, with conglomerate beds, the pebbles being mostly jasper in a sandy matrix of different colors; compact argillaceous limestones, shales, sandstones, and red indurated marls, red and white sandstones and red and white conglomerates, interstratified with diabase layers. These are covered by an enormous amount of trappean overflow crowning the formation, this overflow gives a singularly wild and weird aspect to the country; high, flat-topped hills or ridges, rising with sheer cliffs along the shores of Lake Nepigon and inland, making a strikingly odd landscape.

The rocks of the Animikie (which by the way means thunder, named after Thunder Bay district), are represented by (1)

greenish arenaceous conglomerates with pebbles of quartz, jasper and slate; (2) thinly bedded churts, mostly of a dark colour with argillaceous and dolomitic beds; (3) black and gray shales, with sandstone and ferruginous dolomitic bands, together with layers and intrusive masses of diabase.

I have named and classified these rocks rather fully, as they are of much importance in this district owing to the economic minerals associated with them.

Every one has heard of the Silver Islet mine near Thunder Cape. This mine is in the Animikie, together with a great many other mines that have been worked with considerable profit.

By far the greatest region I explored is covered with the Keweenawan series, but it is not so extensive as is shown on the geological maps of that region. And it is encroached on by the Laurentian from the west and also by a considerable area of Laurentian gneisses around Black Sturgeon lake. This formation yields lead, iron and copper. It is to the iron that I wish to refer more particularly. Two iron deposits were found in the Keweenawan region, one on the east side of Black Sturgeon lake, and another to the north-east of Dog lake. These deposits are large and consist of very good hematite. Undoubtedly with further prospecting more iron will be found. The iron appears close to the contact between the Laurentian and Keweenawan formations. Numerous lead and copper deposits have been found in this series of rocks, and as there is an extensive area of them in the district I explored, I am sure that new and valuable finds will be made when the country is opened up.

Evidently the Huronian areas travelled over are not barren, as I picked up a piece of pyrrhotite in this region that assayed 0.75% nickel and a trace of copper and silver.

Large deposits of beautiful marble are reported to be in the interior of this region, and samples have been brought out but I was unable to see them. Some of the sandstones and impure dolomites would make splendid building stone, while the whole world could be supplied with the very best road material in the shape of the tough fine grained traps that are found. A very peculiar thing in this formation is the occurrence of brine springs, which are

found in numerous places, the salt can be seen in the bottom of them in the shape of white grains. In former years the Indians used to get their supply of salt from these springs.

The chief question is what will this country be good for. I do not believe that more than twenty-five per cent. of the land is fit for cultivation, as the soil is too sandy and rocky, but there are patches of splendid land that could be cultivated. Good root crops could be grown and the hardy kinds of grain. The other seventy-five per cent. is taken up by lakes, rocky hills and muskeg, the latter affording a large amount of first class peat.

With the exception of a few patches of burn the whole country is covered with a healthy growth of timber. This district I believe was once a large white pinery but has been burnt over and replaced by other mixed conifers as the jack pine, spruce and balsam; evidences of this are to be seen all over the country in large scattered pine on the remains of dead ones. Unless nurseries are started as proposed by the forestry commission this country will never be a white pine country. As regards the spruce there is a tremendous quantity and this will be a great asset to the country; when we consider that "a cord of wood manufactured into cheap newspaper may be valued at $40, but would only be worth $7 sawed into lumber" also the manufacturing of wood pulp and the sawing of lumber could be carried on in this district economically, owing to the water power to be found close at hand, providing that railway communication could be got. As regards the other timber, large tamarac is to be found in the district, this, next to rock elm and oak, makes the best boat building material. Unfortunately wooden boats are no longer built, but for piles and railroad ties and lumber this timber should be very valuable. Undoubtedly the jack pine will find a place as a marketable tree some day. At present it is represented as the most worthless tree we have got. Nevertheless it does make good pulp and railroad ties. So we are forced to look on this wood as of some value. Taking the district as a whole the timber represents the most valuable asset. At present, near the Canada Pacific Railroad, numerous pulp wood camps are operating, employing over six hundred men, the pulp wood being shipped to the United States and Canadian manufactories.

What Lake Nepigon and the Nepigon river is chiefly noted for is its wonderful speckled trout fishing; people travel for miles to enjoy a couple of weeks fishing on this beautiful river. Americans are forced to pay about $25 license for the privilege of fishing, while people in Ontario pay $5. During the summer months this river swarms with disciples of Isaac Walton, and the Indians derive a considerable income by acting as guides and canoemen.

As the pulp wood industry develops care should be taken that the fish in this river are protected and not killed out by the debris and rubbish which follows the using of a river for driving purposes and has caused so much harm to other rivers where fish were to be found. The protection of the fish in this lake and river should not be treated lightly, and strong efforts should be made to keep it clear and free from any filth that is likely to kill the fish. A larger income can be derived from selling licenses.

I have mentioned the prospects for mining development in this country, nothing definite can be said till further exploration is carried out.

Another asset to the country is the fur trade. At present the Hudson Bay Company with a few rival companies control the whole output. This region at one time was very rich in fur-bearing animals, but they are getting fewer in number and the trade is nothing as compared to twenty years ago. The caribou, moose and black bear are to be found, but are not plentiful. All the common animals are found, such as the beaver, mink, otter, etc.

The rivers in the district are rapid as a rule, with many falls, and as a number of them have a considerable volume and steadiness of flow, no great difficulty would be found in finding numerous places where power plants could be installed.

I have spent four summers in other parts of New Ontario, and have tried to observe carefully any natural resources that may come under my notice. Although I have seen better districts along the height of land farther east than this region, as regards timber, soil and game, yet taking it as a whole, I believe this country will prove of great value, not perhaps as a farming country, but rather as a lumbering, mining and game country. It will never be thickly populated, but still men will be able to derive wealth, if not great fortunes, by the development of its natural resources.

RATIO OF THE CYLINDERS OF A COMPOUND ENGINE AND WHAT TAKES PLACE IN THEM.

By Wm. Hemphill, Grad. S.P.S.

In taking up the subject of the compound engine or a steam engine of any kind, some authorities consider that practically everything is known about the engine, but I will endeavour to show that we have something to learn and prove about the expansion of steam and the ratio of the volumes of the h. p. and l. p. cylinders.

I will assume I have a compound engine before me all ready running, and I will first explain what takes place when the steam enters the cylinder and follow it throughout the stroke. For this I will not assume any given ratio between the volumes of the h. and l. p. cylinders, but that expansion takes place in each cylinder. For uniform action it would be better to have the engine running a short time, all parts being thus warmed up, so that cold metal will not interfere with any suppositions.

When the steam enters the h. p. cylinder from the steam chest it is at a certain pressure and the corresponding temperature; it may also be considered saturated. Just as the valve opens to allow the first portion of the steam to enter the h. p. cylinder, the cylinder and the piston are at a lower temperature than the entering steam, so some of the steam is immediately condensed, and this continues until the cylinder becomes the temperature of the entering steam, *i.e.*, the portion of the cylinder between the piston and the end of the cylinder that is open to the live steam. The piston is pushed forward to the point of cut-off and now the steam commences to expand and continues expanding until the point of release is reached. During this expansion the pressure of the steam decreases, consequently its temperature lowers; but the steam contained a certain amount of heat when it entered the cylinder, so if we had a perfect engine from which no heat could enter or escape, the heat liberated by the fall of temperature caused by

lower pressure, would be taken up in the steam which would be superheated during expansion, and the steam that was condensed at the first part of the stroke would be evaporated again, but as we have not an ideal engine to work with, we do not get such perfect results. The heat that is liberated by the fall of temperature is partly used in heating the cylinder walls as the piston moves out, exposing new portions of the walls to the steam, some of which heat may be used in re-evaporating the water caused by initial condensation. In fact this seems to be reasonable, for in working out tests we find as a rule a little more steam in the cylinder at release than at cut-off. Now release occurs and the steam is exhausted into a receiver or the l. p. steam chest. During exhaust the steam

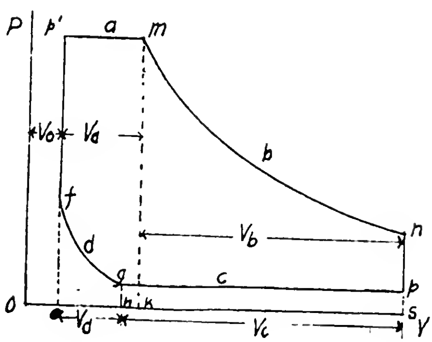


Fig. 1

is superheated owing to the large quantity of heat that is liberated by the drop in pressure. Then the l. p. cylinder takes the steam from the receiver and it is still further expanded until release occurs and the steam is exhausted into the condenser or air, according as the engine is condensing or non-condensing. Now with this rough idea of what takes place during the stroke, I will follow it out more particularly.

By following a method known as Hirn's Analysis we can determine the work done in thermal units for different parts of the stroke. In Fig. 1 the portions of the stroke are indicated by the subscript letters, thus a for admission, b for expansion, c for exhaust, d for compression. Then—

Va = volume in cu. ft. described by piston during admission.

Vb = volume in cu. ft. described by piston during expansion.

Vc = volume in cu. ft. described by piston during exhaust.

Vd = volume in cu. ft. described by piston during compression.

Vo = volume in cu. ft. of clearance space.

V = whole volume displaced by piston.

Let the work done in thermal units by the steam during the several portions of the stroke be represented by T with its appropriate subscript, thus—

Ta = work done during admission = area ep'mke in B. T. U.

Tb = work done during expansion = area Kmnsk in B. T. U.

Tc = work done during exhaust = area h g p s h in B. T. U.

Td = work done during compression = area e f g h e in B. T. U.

$Ta + Tb$ = absolute work done by steam = area ep'muse.

$(Ta + Tb)—(Tc + Ta)$ = net area of indicator diagram.

The quantities of heat in thermal units exchanged between the steam and the metal are represented by areas Ra, Rb, Rc, Rd, the areas being drawn to the same scale as the work diagram.

Ra = heat exchanged between metal and steam during adm."

Rb = heat exchanged between metal and steam during exp."

Rc = heat exchanged between metal and steam during exh."

Rd = heat exchanged between metal and steam during comp."

E = heat lost by external radiation.

Q = the quantity of heat supplied to cylinder per stroke by admission steam.

Q^1 = the quantity of heat supplied from jacket.

$Q + Q^1$ = total heat supplied.

Let M lbs. = weight of wet steam admitted per stroke, of which Mx is dry steam, and M (1—x) is weight of water present in steam. Let also the weight of steam retained in the clearance space each stroke = Mg. (The actual weight of this steam may be measured knowing the pressure g at beginning of compression.) Then the heat Q required to raise M lbs. of water from 32° F. to its temperature of admission, and to evaporate the portion Mx is $Q = M(h + xL)$ [h is sensible heat L = latent heat of steam].

3

For superheated steam heated from normal temperature tn of saturated steam to temperature ts—$Q = M\ [h + L + .48\ (ts - tn)]$.

The internal heat of the steam in clearance space at commencement of compression, assuming the steam dry$=Mg\ (hg+lg)$.

Where Mg, hg, lg represent weight, sensible heat, and internal heat at pressure and volume at point g on the diagram Fig. 1.

The internal heat at cut-off$=(M + Mg)\ (hm + {}^{x}m\ \rho m)$, where ${}^{x}m =$ dry steam fraction on the diagram.

The internal heat at end of expansion—

$$= (M + Mg)\ (hn + {}^{x}n\ \rho n)$$

and similarly for the other points of the cycle.

Now to find the heat Ra. The heat supplied is Q, the heat in the cylinder at admission is—

$$Mf\ (hf + xf\ \rho f)$$

the work done is Ta; and the heat remaining in the steam at cut-off is $(M + Mg)\ (hm + xm\ \rho m)$. Then—

$$Q + Mf\ (hf + xf\ \rho f \quad Ta + Ra + (M + Mg)\ (hm + xm\ \rho m).$$

from this can find Ra as all other quantities known.

To find Rb. The heat in the steam at the end of expansion is $(M + Mg)\ (hn + xn\ \rho n)$; the exteneral work is Tb, the heat present at beginning of expansion is $(M + Mg)\ (hm + xm\,\rho m)$. then—

$$(M + Mg)\ (hm + xm\ \rho m) = Tb + Rb + (M + Mg)\ (hn + xn\ \rho n).$$

from which Rb may be determined.

To find Rc. The heat in the steam at end of expansion is $(M + Mg)\ (hn + xn\ \rho n)$: the work done upon the steam during exhaust is Tc; the heat in the steam at beginning of compression, assuming the steam at compression dry: is $Mg + xg\ \rho g)$.

To determine the heat rejected to the condenser must be done by a test of the engine, and weighing the steam condensed in a given time, and dividing this weight by the number of strokes made by the engine in that time. This will give the weight of steam M exhausted per stroke. Then M lbs. of steam become water at temperature t. The heat in this condensed steam is now Mht. The heat carried away by the condensing water equals the

weight of condensing water W per stroke multiplied by its increase of temperature in passing through the condenser $= W\ (t_1 - t_2)$. Then:—

$$(M + Mg)\ (hn + xn\ \rho n) + Te = Re + Mht + W$$
$$(t_1 - t_2) + Mg\ (hg + xg\ \rho g\ .$$

from which Re may be obtained.

To find the heat Rd. The internal heat in the steam at beginning of compression is $Mg\ (hg + xg\ \rho g)$. Then work is done upon it $=$ Td during compression; and the internal heat of the steam at end of compression is $Mf\ (hf + xf\ \rho f$: then—

$$Mg\ (hg + xg\ \rho g) + Td = Mf\ (hf + xf\ \rho f) + Rd.$$

from which Rd may be found. This applies to one cylinder, by taking the other indicator card this may be applied to the l.p. cylinder.

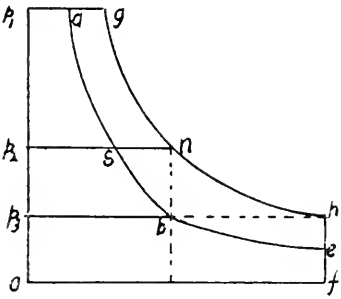


Fig. 2

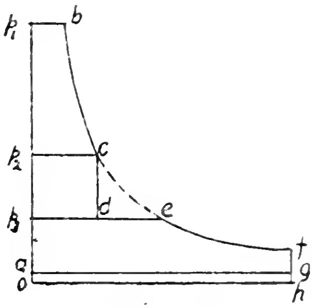


Fig. 3

We are now in a position to follow the diagram of Figs. 2 and 3, and follow the action in the cylinder on other lines than heat units.

To do this it will be more satisfactory to assume some definite proportions, let the ratios of the cylinders be 1:2; the cut-off in the l.p. cylinder to be constant at .5 of stroke and to enclose a volume at cut-off equal to the volume of the h.p. cylinder. Then the distribution of power between the cylinders may be shown by Fig. 2, in which I assumed hyperbolic expansion. In practice this diagram would be subject to a number of changes, but it illustrates in a very satisfactory way various results in a compound engine.

Take cut-off at .25 of the stroke in the h.p. cylinder and at an initial pressure p, shown on Fig. 2, the steam expands along a b until it reaches the pressure $p_3 = p_1 \times .25$ neglecting clearance (this is also the pressure in the receiver). The work diagram of the h.p. cylinder equals area p_1 abp$_3$, and of the l.p. cylinder the area p_3 befo, point b being the cut-off in the l.p. cylinder.

Suppose now we make the cut-off in the h. p. cylinder at .5 of stroke, then nearly twice the weight of steam is supplied per stroke, and the steam at release is at a higher pressure than when cut-off occurred earlier. Call this pressure p_2 as shown on Fig. 2, and the pressure of the receiver, p_2, is the back pressure on the h.p. piston and the forward pressure on the l.p. piston to the point of cut-off at n now, and the work diagram is now given by the areas p_1 gup$_2$ and p_2 nhfo by the small and large cylinders respectively. A glance at fig. 2 shows the difference in the work by changing the point of cut-off in the h.p. cylinder; it shows a marked increase in work for the l.p. piston, while the h.p. work is practically the same.

Thus we find to increase the power of the engine we have to increase the per cent. of cut-off, but the larger share of the increased power comes from the 1 p. cylinder: while with early cut-off and low power the larger share of the work comes from the h.p. cylinder. And as this power can be decreased to a minimum, the power of the l.p. cylinder may be reduced to zero.

Now consider the effect of throttling the steam supply with the same ratio of cylinders, and cut-off fixed in both cases at .5 of stroke without "drop." The initial pressure was p_1 before and let it be throttled to $p_2 = \frac{1}{2}p_1$. Then in fig. 2, the distribution of work is seen as area p_2 sbp$_3$ for the h.p. cylinder and p_3 befo for the l.p. cylinder. This shows the work area for the l.p. cylinder the same for steam throttled as with high pressure, with cut-off at .25 of stroke, but the work area in the h.p. cylinder is much less, when the steam is throttled, giving a less satisfactory distribution of power between the cylinders for throttling than having cut-off earlier. It shows that theoretically, throttling to a pressure p_2 is *less* economical than changing the cut-off from .5 to .25 with constant initial pressure, for in both cases the same weight of steam

is exhausted per stroke, *i.e.*, the l.p. cylinder volume at pressure f e, though with throttling the useful work area is reduced by the area p_1 asp_2. This theoretical gain would not all be realized in the actual case owing to cylinder condensation with an early cut-off.

Another way of remedying the unequal distribution of power between the cylinders is by having a variable cut-off in the l.p. cylinder. Let us take the cylinder ratios 1:4 and cut-off in each cylinder at half stroke, and let p_1 $bedp_3$ fig. 3, be the work area of the h.p. and p_3 efga the work area for the l.p. cylinder. Now change the cut-off in the l.p. from .5 to .25 of the stroke; then the work areas will be changed, the h.p. being p_1 bep_2 and the l.p., p_2 efga. Conversely if the cut-off in the l.p. be made later then the work area in the h.p. will be increased, and decreased in the l.p. cylinder.

In the above methods the effect of the receiver between the cylinders was not taken into account. In the majority of compound engines a receiver is placed between the cylinders to receive the exhaust steam from the h.p. cylinder and to give it to the l.p. cylinder. This receiver often takes the form of a pipe and the valve chest. (The above has reference to a cross-compound engine.)

Now if this area were indefinitely large, the back pressure line of the h.p. and the forward pressure of the l.p. cylinder, would be each a horizontal straight line. In practice the receiver volume is from 1½ to several times the volume of the h.p. cylinder. The effect of the restricted volume of the receiver is to make the back pressure line of the high and the admission line of the low-pressure diagram irregular.

The receiver volume is made as small as possible to avoid radiation of heat, but space is an important factor to consider in the size of the receiver. The effect of a small receiver is to increase the small cylinder's back pressure and to increase the initial pressure of the large cylinder. Sometimes an increase in pressure occurs in the l.p. cylinder towards the point of cut-off, which is caused by the h.p. cylinder's exhaust passing into the receiver before cut-off has taken place in the low.

In designing an engine it is usual to get the diameter of the l.p. cylinder first, and then the diameter of the h.p. cylinder depends on a number of conditions, but the main object is to have the power evenly divided between the two cylinders. After looking through a number of catalogues, I find the ratio of the volumes of the cylinders range from 1:2½, 1:3, and 1:4, rarely higher, or the diameter of the l.p. cylinder is twice that of the h.p. cylinder minus two. Nearly all the manufacturers cling to this idea of ratios, which later on I will endeavor to show is an error in the point of economy in the engine.

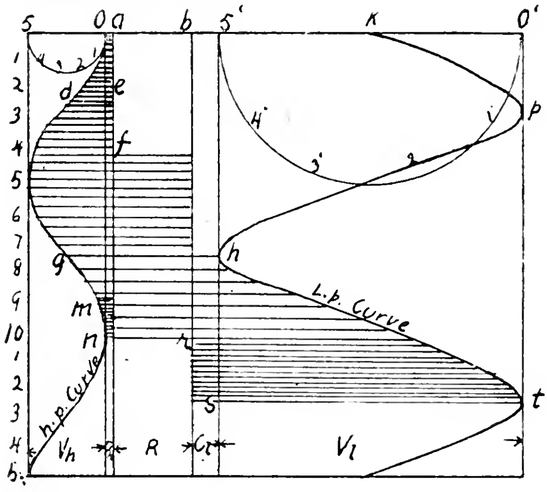


Fig. 4

Let us now construct a diagram which will show the piston displacement in a compound-engine. To do this it is necessary to assume ratios of cylinders, clearance and receiver volumes for a given compound-engine. By this diagram it will be possible to follow the steam through the engine, and it illustrates the changes of volume and pressure between the points of entering and leaving the cylinder.

In fig. 4, horizontal lines are lines of volume, and vertical lines are divided into portions of a revolution. Then let aO = volume of h.p. clearance (Ch); O5 = volume of h.p. piston displacement (Vr); ab = volume of receiver (R); b5' = volume of

l.p. clearance (Cl); and 5′O′ = volume of l.p. piston displacement (Vl).

On the lines O5 and O′5′ draw semicircles representing half a revolution of the crank-pin and divide it into any number of equal parts, say five. On the vertical line to the left of fig. 4, set off ten equal parts representing parts of a revolution. The diagram shown is for one and a half revolutions. The cranks are assumed at right angles, when the h.p. piston is at beginning of stroke O and the l.p. piston is at centre of stroke K. Through the points on the vertical line numbered 1, 2, 3, etc., draw horizontal lines, let these intersect the vertical lines drawn through the numbers on the semicircle, the intersection of these lines for the corresponding number gives a point on the "curve of piston displacement." Obtain a number of these points for both cylinders and the curves can be swept in as shown. The different grades of hatching show the volumes in the cylinder as admission to h.p. cylinder, expansion in h.p. cylinder, etc. It is easily seen from the figure all these points and also the connection between the two cylinders. The h.p. clearance Oa is first filled with steam at initial pressure, and the steam is continued to the point of cut-off at half stroke, and volume in cylinder = de. The steam is then expanded to nearly the end of the stroke, when the exhaust port opens, and at f the steam passes into the receiver. Now the exhaust side of the h.p. cylinder and the receiver are in communication, as shown, until the l.p. steam port opens at h. Here the volume of the steam = gh. At m the h.p. exhaust port is closed, and compression begins. At the point r in the l.p. piston cut-off takes place and the steam expands to volume st. This diagram can be applied to the indicator diagrams of compound engines as shown fig. 5.

This figure shows the piston displacement curves for cranks at right angles, the theoretical indicator diagram of the h.p. cylinder being drawn below the h.p. piston curve, and the l.p. indicator diagram below the l.p. curve. The initial pressure is known, and is set up from the zero line of pressure. In the diagram cut-off occurs at .4 of stroke in the h.p. cylinder, and as the initial pv is known, all other points in the cycle may be determined, assum-

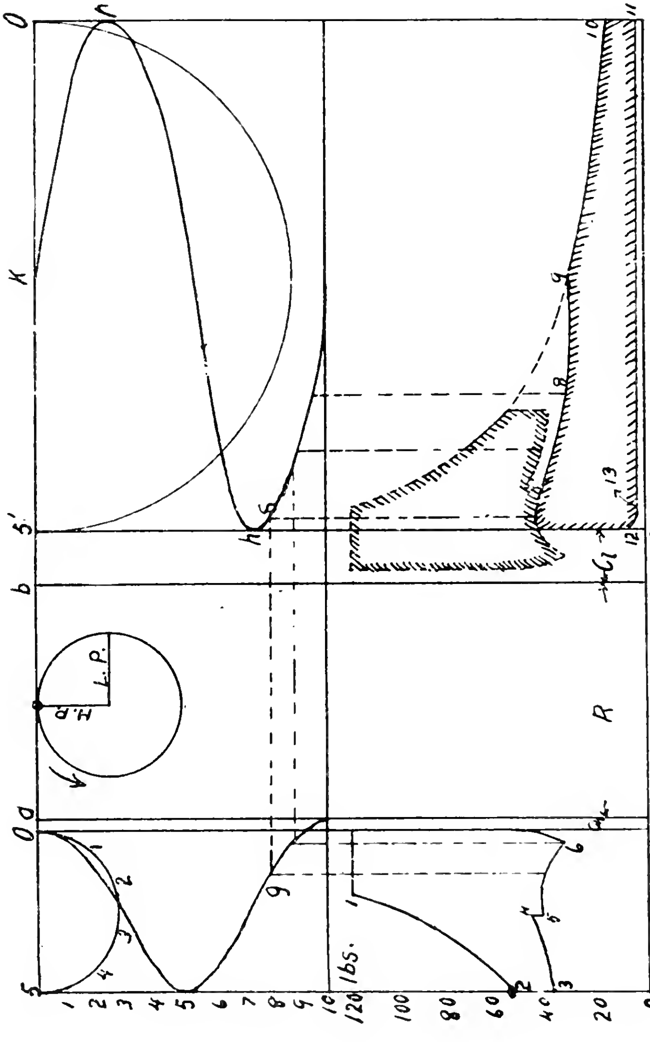


Fig. 5

ing hyperbolic expansion. In the following equations the subscripts refer to the figures on the portions of the diagram representing the theoretical indicator diagram. Thus V_3 = volume of steam at point 3, measured from beginning of stroke, *i.e.*, from vertical line Oa and to the left in the h.p. diagram, and from vertical line through B and to the right in the l.p. diagram. When the exhaust side of the h.p. cylinder is in communication with the l.p. cylinder, then the volume including that of the receiver, is given by the horizontal intercept between the lines of piston displacement.

For this diagram it may be assumed that pv = a constant, then:—

$$p_1 (v_1 + Ch) = p_{10} + Cl),$$

from which the terminal pressure is obtained, and the point of cut-off in the l.p. cylinder being known, then—

$$p_9 (v_9 + Cl) = p_{10} (v_{10} + Cl),$$

from which p_9 or the pressure at cut-off in the l.p. cylinder, and therefore the pressure in the receiver at that time is known.

Then the pressures at all other points may be obtained by the following equations:—

Referring to the theoretical diagrams in the lower part of fig. 5, then for the h.p. cylinder

$$p_1 (v_1 + Ch) = p_2 (v_2 + Ch).$$

At point 2 the steam exhausts and mixes with that in the receiver, which is at some pressure p_9 previously calculated.

$$p_2 (v_2 + Ch) + p_9 R = p_3 (v_3 + Ch + R).$$

But during the return of the h.p. piston, so long as the l.p. cylinder is not open to receive steam, the volume enclosed is for the moment reduced, hence the pressure rises to p_4 until the l.p. valve opens the port to steam, when the pressure instantly falls to p_5, then—

$$p_3 (v_3 + Ch + R) = p_4 (v_4 + Ch + R).$$

When the l.p. valve opens to steam, the receiver steam mixes with that in the clearance space of the l.p. cylinder; thus—

$$p_4 (v_4 + Ch + R) + p_{12} Cl = p_5 (v_5 + Ch + R + Cl).$$

This action continues, and meanwhile the l.p. piston is moving forward and increases the displacement, causing the pressure

to fall to p_6, when the h.p. exhaust valve closes, and compression begins in the h.p. cylinder; then—

$$p_5 (v_5 + Ch + R + Cl) = p_6 (v_6 + Ch + R + Cl + v_8).$$

where v_8 is the volume displaced by the l.p. piston from the beginning of its stroke, and which volume may be measured by the horizontal intercepted between the lines of piston displacement, as shown by the dotted projectors. The back pressure p_{11} in the l.p. cylinder is fixed—

$$(p_{12} \; Cl) = p_{11} (v_{13} + Cl).$$

The same principles may be further extended to represent changes in any number of cylinders taking two at a time. In fig. 5 the h.p. diagram is shown dotted over the l.p. diagram to show more clearly the relation between them.

In what I have said so far on the compound-engine it was not necessary to take into account the ratios of the volume of the h. and l.p. cylinder; all the assumptions that were made were very limited, as I only wanted to show what took place in the cylinders, to follow the steam through the stroke, illustrating it by diagrams, and also how the work was divided up, giving the latter in heat units as well as work units. It is now my intention of dealing with the ratios of the volumes of the cylinders, and endeavor to show that it is an error in assuming that everything is now authoritatively settled about the design of the steam engine which seems to be the prevailing idea in the minds of those who write text-books on thermodynamics and heat engines, although in a general way this idea may be accepted as true, for the steam engine of James Watt considered as an automatic mechanism was not different in any essential particular to what we have to-day. The fact of cylinder condensation was known then although not understood to the extent that it is to-day.

A great many compound corliss and marine engines have been built in the last twenty or thirty years, but only in the last eight or ten years has anything been known experimentally of the most economical volumes of cylinder ratios. We see, as I mentioned before, that in Europe and America the ratios run from 1:4. The reason of this is the fact that an engine so proportioned avoids more than a very slight "drop" in pressure from that at the end

of expansion in the smaller cylinder to the pressure at cut-off in the large cylinder, with reasonable ratios of expansion in each. When "drop" occurs it is because free expansion takes place, caused by the sudden enlargement of the volume of the steam without doing work against a piston. As this "drop" is not reversible in the idea of a cycle it is considered loss. Since the time of Watt's invention the steam pressure has been increasing, but no change has been made in the ratios of the cylinders. So far as I can learn Carl Busley, Professor at the German Imperial Academy at Kiel, is the only authority who would change the ratios of the cylinders in compound engines for different steam pressures. He gives the following ratios:—

Pounds per sq. in.	60	90	105	120
Ratio	1:3	1:4	1:4.5	1:5

Professor Ewing is very positive in his statement that care should be taken not to allow free expansion into the receiver as "drop" occurs which would be shown on an indicator diagram by a sudden fall at the end of the h.p. expansion. All these statements about "drop" being wasteful were assumed, no one taking the trouble to perform experiments to prove the supposition. It is true that "drop" is wasteful, but I think the effect of allowing this "drop" can be utilized to make "drop" a gain in the end. The "drop" I refer to must not be mistaken for the drop caused by sudden radiation or condensation, but that resulting from intermediate expansion, although it looks as if authorities put the two together under the same head. In D. K. Clark's Rules, the following discussion occurs on the influence of "drop."

"That the work of expanding steam is to be calculated from the expansion upon a moving piston only is obvious enough when it is considered that the steam may expand into an intermediate receiver, and into intermediate passages, without doing any work on a piston, whilst at the same time the pressure falls or drops as the volume is enlarged. Under these circumstances the second cylinder receives the steam at a lower pressure and in larger volume than it has when there is no intermediate expansion and fall of pressure, and there is less work done, whilst the ratio of active expansion is necessarily reduced. If the second cylinder, however,

be enlarged in capacity in proportion to the enlargement of the volume of steam and the fall of the pressure by intermediate expansion, the ratio of expansion and the work done in it would remain the same." These quotations considered by themselves would commit Clark to the common belief that "drop" produced by intermediate expansion causes a serious waste. He goes a little farther in the right direction than others have done, however, in the suggestion that the waste occasioned by "drop" may be balanced by enlarging the second cylinder; but he does not, in this immediate connection, draw attention to the fact that the loss in pressure of the receiver steam, due to the practice of taking more steam by volume from the receiver than it gets from the h.p. cylinder is accompanied by an increase of work in the h.p. cylinder. By this the back pressure in this cylinder is reduced and at the same time the initial pressure in the l.p. cylinder. Therefore the loss occasioned by receiver expansion is much less than Clark implies in his quotation, and if high boiler pressures are used with a moderate amount of "drop" this loss, even from a thermodynamical point of view is quite insignificant. Let us now consider the causes of "drop" and the advantages that accompany its moderate use.

There are two causes of "drop." The first is intermediate expansion. When more steam by volume leaves the receiver than is put into it per stroke (assuming no steam made or condensed in the receiver), the receiver pressure must be less than the pressure in the h.p. cylinder at release. The other cause of "drop" is cylinder condensation and clearance in the l.p. cylinder. If a receiver compound engine had neither clearance or condensation in the l.p. cylinder, there might still be any amount of "drop" if the cut-off on that cylinder were lengthened enough. Again, if the cut-off were adjusted just right to prevent any "drop" in such an engine, and the cylinder had the usual amount of clearance and condensation, a "drop" of from 12 to 15 pounds might result. Even this could be prevented by making the cut-off earlier in the stroke. Therefore it is seen that cut-off may be a cause or a corrective of "drop." But the point of cut-off is dependent on considerations other than its effect on drop. It would be desirable

to have the cut-off occur late in the stroke were it not for the loss of excessive free expansion, as this would reduce the range of temperature of the l.p. cylinder walls, and would, therefore, reduce the loss from initial condensation in this cylinder.

It is easily seen from the foregoing that unless the best point of cut-off, chosen with reference to the waste by initial condensation happens to coincide with that particular point at which "drop" would be entirely prevented, a compromise must be made between the gain by lengthening cut-off and the loss by free expansion. This does not have to be done in cylinder ratios of 1:3, but it is necessary for larger ratios as 1:6 or 1:7. If "drop" is accompanied by a reduction of initial condensation in the large cylinder, in amount sufficient to overbalance the waste of power by intermediate expansion, it is at least, no detriment to the coal consumption to allow that much "drop." This "drop" is considered very useful in plants driving a varied load, as it allows a widely variable cut-off in the second cylinder without either looping at the end of expansion in the first cylinder or materially changing the receiver pressure.

After dealing at some length with intermediate expansion it would be well to consider some of the general theory of the compound engine. We will assume the proposition that the highest economy to be obtained in an engine of any type is the result of two conditions—using a volume of steam at the highest possible pressure and expanding it the greatest number of times. But we find both the pressure and expansions are limited by practical circumstances; the pressure by the increase in cost of boilers and piping, while the ratio of expansion, by the increase in waste due to cylinder condensation, friction and repairs. All the authorities appear to agree that there is a minimum number of expansions allowable in each cylinder. This number is between four and five. But in an engine with cylinder ratio 1:3, practically no "drop" will occur, and custom has limited the number of expansions for such an engine to 12 or possibly 15. A steam pressure of 115 pounds for such an engine gives the best result as to economy. A higher pressure would enable the engine to do more work, but the number of expansions remaining the same the steam

consumption would not be affected. Now if higher pressures are going to be used with the idea of improving the economy, it would be necessary to add another cylinder so that increased expansion could take place. The average pressure for triple expansion engines is from 150 to 160, and even higher; but with the usual ratio of cylinders—1:2.75 :6.5—the number of expansions in each cylinder would be much less than that given above. The reason of this is that 150 pounds pressure is not enough to permit the larger number without developing too little pressure at release in the l.p. cylinder.

Now in the triple expansion engine we have increased the engines from two to three, as a compound engine really consists of two engines, each requiring the same number of parts and the same equipment all through. To this we have added the third which will increase the cost of the engine, an important item in the majority of cases. The volume of steam in the h.p. cylinder is expanded from that volume to the volume of the l.p. cylinder; it is not done direct but through the intermediate cylinder, but amounts to the same thing in the end. Now for mill engines and all stationary plants I think that this increased expansion could take place in the two cylinders instead of three. In fact I find for stationary work the compound engine is preferred to the triple expansion engine. Now I think if the ratio of the cylinders in the compound engine were increased to 1:7 or 1:8, and perhaps even greater for mill work, or any stationary work, the economy in fuel would be nearly if not quite equal to the triple expansion engine. The only way to prove this is to perform a number of tests on each kind of engine, *i.e.*, the triple expansion and a compound engine of different cylinder ratios, some large and some small. I do not say that the compound engine, with large ratios, will prove the more economical with regard to fuel and water supply, but if the pressures in each case are, say 180, it will hold a very high place.

I will now give a few results of some tests with regard to fuel and water, that have been obtained by competent men on compound engines using the ordinary ratio of the volume of cylinders. One of the large ratio I have considered above, also a triple

expansion engine. The results will speak for themselves, and I think the large ratio for compound engines will soon be taken up more favorably, and will take the place entirely of the triple expansion engine, although I think, in marine work, the triple expansion engine should be retained, if only for mechanical reasons. So far as I can learn I think there have been only a few of these engines made with the large ratio for the cylinders. These were made by the American Wheelock Engine Company, and all but two surpassed the makers guarantee for fuel and water supply.

Test 1.

Kind of engine—Cross-compound Wheelock engine, made by Goldie & McCulloch, Galt, Ont.

Ratios of cylinder, volumes 1:3.4.

Steam pressure, lbs. 82.5.

I. H. P. 239.

Coal per I. H. P. hr. 1.9.

Water per I. H. P. per hr. 17.2 lbs.

Test 2.

Kind of engine—Tandem-compound, four valve type, made by Russel Engine Co., Massillon.

Ratios of cylinder volumes 1:4.3.

Steam pressure 160 lbs.

I. H. P. each engine 300.

Coal per I. H. P. per hr. 2.55 lbs.

Water per I. H. P. per hr. 15 lbs.

Test 3.

Kind of engine—Cross-compound, made by American Wheelock Engine Co.

Ratios of cylinder volumes 1:7.2.

Steam pressure 140 lbs.

Cut-off h.p., .287 of stroke; l.p., .236 of stroke.

I. H. P. 650.

Coal per I. H. P. per hr. 1.18 lbs.

Water per I. H. P. per hr. 11.89 lbs.

Test 4.

Kind of engine—Allis triple expansion pumping engine.

Ratios of cylinder volumes 1:2¾ :4½.

Steam pressure 185 lbs.

I. H. P. 750.
Coal per I. H. P. per hr. 1.02 lbs.
Water per I. H. P. per hr. 10.48 lbs.

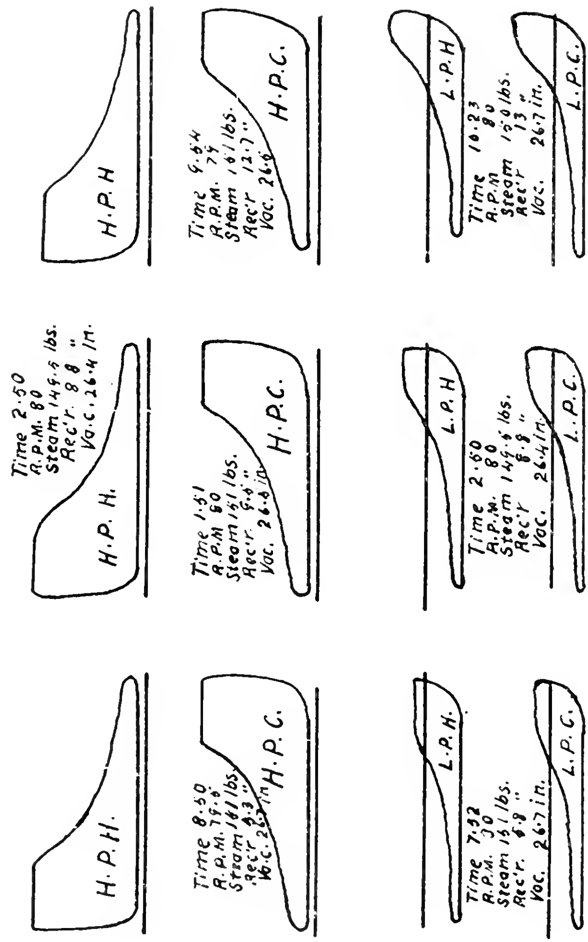


Fig. 6

Fig. 6 is a copy of some indicator cards taken from the engine while Test 3 was going on. The cards are very good and there is nothing to indicate in the l.p. cards that the increased volume is detrimental.

THOMSON RECORDING WATTMETER.

C. G. Carmichael, '01.

While comparisons between the meter and contract systems are no longer necessary, the choice of a meter is an important consideration: Shall it be an ampere meter registering the current, or a wattmeter registering the energy? To answer this let us examine effects of voltage on a 16 candle power, 3.1 watt incandescent lamp. A variation in voltage of 3% from normal is quite common, but the 2% variation given in Table 1, is quite sufficient for our purpose.

Table 1.—Effects of voltage on a 16 C. P., 3.1 watt incandescent lamp. Normal voltage 100.

Volts.	Candle p'w'r	Watts per Candle	Amperes	Total Watts
98	14·40	3·33	0·485	47·5
99	15·20	3·21	0·492	48·8
100	16·00	3·10	0·496	49·6
101	16·96	3 00	0·504	50·8
102	17·92	2·91	0·512	52·2

Suppose the Electric Light Co. is able to dispose of its power at the low rate of 10 cents per kilowatt hour. From Table 1, we see that a 16 C. P., 3.1 watt lamp at normal voltage takes 0.496 amperes. Since an ampere meter is calibrated from an indicating wattmeter, the voltage being kept constant at normal for this case a rate of 10 cents per K. W. H. is same as 1 cent per ampere hour. Also here a rate of 10 cents per K. W. H. is same as 0.031 cents per candle power hour.

We can now deduce the following table of charges per lamp hour, according to above three methods.

Table 2.—Charge per lamp hour.

Voltage	Charge per lamp hour at 10 cents per K. W. H.	Charge per lamp hour at 1c per ampere hour.	Charge per lamp hour at 0·031c. per candle pow'r hour.
98	0·4751c	0·485c	0·4464c
99	0·4880	0·492	0·4712
100	0·4960	0·496	0·4960
101	0·5088	0·504	0·5258
102	0·5220	0·512	0·5555

It can thus be seen that when voltage is below normal the ampere meter records more power than is used, and when voltage is above normal this same meter records less power than is actually consumed. Apparently it might therefore be argued that it would pay to use ampere meters and keep the voltage low. But any Electric Light Co. could soon tell you how many customers it would have at the end of a year were it to supply only 14 C. P. and charge for 16 C. P.

Now consider the customer. He wants so much light. Virtually he wants to pay so much per candle power hour. Say he is a merchant and in a year he uses 200 sixteen candle power lamps for 500 hours or 100,000 lamp hours. From Table 2, his lighting bill is found.

For a voltage of 98—

By Wattmeter his bill would be $475.10
By Ampere Meter his bill would be 485.00
His just bill at 0.031 cents per C. P. hour is 446.40

That is Ampere Meter charges him too much by $38.60, and Wattmeter too much by $28.70, that is Wattmeter is more nearly correct by $9.90.

For a voltage of 102—

By Wattmeter his bill would be $522.00
By Ampere Meter his bill would be 512.00
And his just bill at 0.031 cents per C. P. hour is. 555.50

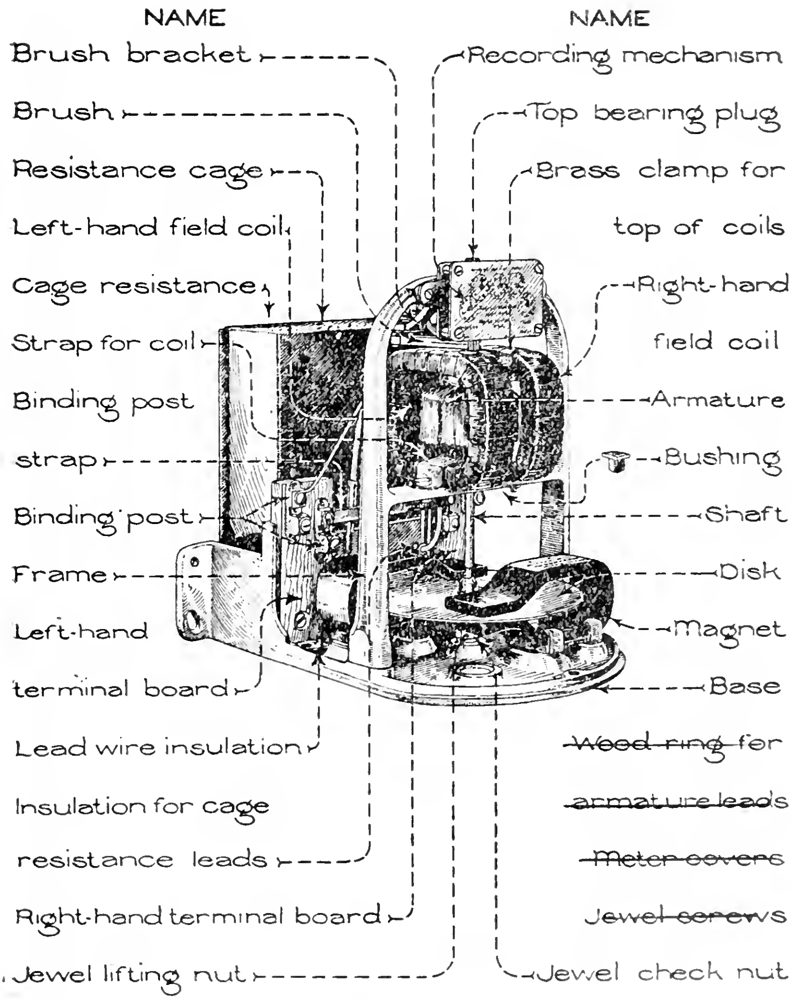
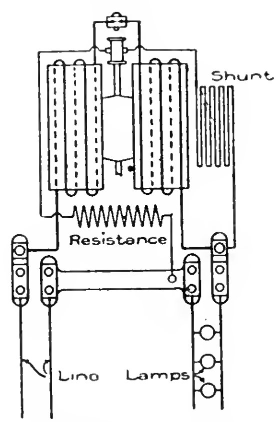

NAME
Brush bracket
Brush
Resistance cage
Left-hand field coil
Cage resistance
Strap for coil
Binding post
strap
Binding post
Frame
Left-hand
terminal board
Lead wire insulation
Insulation for cage
resistance leads
Right-hand terminal board
Jewel lifting nut
NAME
Recording mechanism
Top bearing plug
Brass clamp for
top of coils
Right-hand
field coil
Armature
Bushing
Shaft
Disk
Magnet
Base
~~Wood ring for~~
~~armature leads~~
~~Meter covers~~
~~Jewel screws~~
Jewel check nut

Fig. 1.

That is by registration of current the merchant is charged too little by \$43.50, and by registration of energy too little by \$33.50, again showing a difference, of \$10.00, in favour of the Wattmeter.

The first requirement essential to a perfect recording meter is therefore registration of energy and not current, one of its factors. A meter must be, simple and durable: able to resist tampering and independent of atmospheric conditions; independent of frequency and inductive circuits and must be adaptable to either direct or alternating current.

I will attempt a brief description of the Thomson Recording Wattmeter. In Fig. 1 is shown a 5 ampere, 220 volt meter, the connections being shown in Fig. 2.



Two wire, up to 50 amp

FIG. 2.

It is simply a small motor and dynamo combined. A small fraction of the energy which the meter measures operates the motor, and the retardation is supplied by the light drag of a copper disk rotating between the poles of two magnets.

The armature consists of a number of coils of fine wire wound upon a frame of pressed paper, which is fastened to the vertical shaft. The commutator bars are made of silver and the brushes are tipped with that metal. The armature, in series with a suitable resistance and the shunt, is connected across the line. The fields consist of a number of turns of stout copper wire of size

sufficient to carry a current of twice the rated capacity of the meter. These fields are connected in series with one side of the line the full current passing through them. Hence the torque of the motor is exactly proportional to the watts.

There is no iron about the motor, and the meter when once calibrated is adaptable to either direct or alternating current. In fact were we to replace the brushes by two connections affixed to opposite segments in the commutator and attaching a suitable spring and pointer to the shaft, we would have an indicating wattmeter capable of being used on any circuit.

The copper disk rotates between the poles of two magnets. By moving the magnets out or in the speed is regulated so that the number of revolutions of the disk in a certain time corresponds to energy delivered to the circuit in that time. On the shaft is a worm which operates the recording mechanism.

As before stated the shunt is connected in series with the armature and resistance across the line. It consists of a suitable number of turns of fine wire and is inserted in the inside of one of the field coils. Its object is to assist meter on light loads, thus giving the meter great accuracy on all loads.

In the lower end of the shaft is a polished, hardened steel detachable pivot. The shaft sits on a jewel mounted on a spring in the end of a screw. So that if from any cause jewel or pivot should be damaged both can be easily removed and replaced by new ones without removing the cover. The meter is protected by a metallic cover which is drawn tightly down on to a strip of felt on the base, thus rendering it dust proof. To the underside of the base is fastened a metallic plate, when it is sealed up it is impossible to tamper with the meter without breaking the seals.

Wattmeters are tested by connecting them up with an indicating Wattmeter; and with a stop watch noting the time of a certain number of revolutions of the disk. The formula,

$$\frac{3{,}600 \times \text{constant} \times \text{number of revolutions}}{\text{time (in seconds.)}}$$

gives watts recorded by the recording meter and this should agree with the reading of the indicating wattmeter. If there is not a

close enough agreement the magnets are moved out or in, according as meter is fast or slow.

The formula is derived as follows:

Let 1 revolution of disk in 1 hour = 1 watt hour.

Hence 1 revolution of disk in 1 sec. = 3,600 watt hours.

Or N revolutions of disk in 1 sec. = 3,600 × N watt hours.

Or N revolutions of disk in t sec. = $\frac{3{,}600 \times N}{t}$ watt hours.

Now suppose we took a 25 amp., 100 volt meter and passed 100 amperes at 100 volts. through it, the disk would rotate at the abnormal speed of 166.68 R. P. M. If the field coils were made with one-quarter of the number of turns of wire the torque, and hence the speed of the disk would be one-quarter of what they were before. Since the disk is running at one-quarter of the speed necessary to record the power in the circuit, the dial will indicate only one-quarter of the power, so the dial reading is multiplied by 4, or as it is termed "constant 4." Then formula becomes

$$\frac{3{,}600 \times \text{constant} \times \text{number of revolutions}}{\text{time (in seconds).}}$$

Another way of looking at it is—

Let W = watt hours.

N = number of revolutions.

t = time in seconds.

K = constant.

$$W \propto 3{,}000\frac{N}{t}$$

W ∝ Revolutions per hour.

$$W = K\frac{3{,}600N}{t}$$

By choosing the proper value for $\frac{3{,}600N}{t}$ we can have any value of K, ½, 1, 2, etc., depending on the size of the meter.

Everything should be carefully considered before selecting the proper size of wattmeter to be used. If a building is to be illuminated with 400 lamps it does not of necessity follow that a 400 light meter will do. Take the case of a theatre using 300 sixteen candle power lamps. Probably ten of the lights would be

used a greater portion of the day to light up the ticket office, lobby, etc., and remaining 290 would only be used a short time during a performance. Now I would place a ten light meter on the first mentioned circuit, and a two hundred light meter on the lights in the main part of the theatre. It is far better to have too small a meter on an intermittent load than too large a one.

Heretofore it seems to have been the practice, especially in regard to house lighting, to locate the meter in the most undesirable spot possible. Garrets and cellars are favorite spots. In the former there is a 120° range of temperature between winter and summer, while in the latter it is usually damp. Is it not unreasonable to expect good results from meters located in such places? A good location is any of the back living rooms in the house.

When a meter is set up it should be examined annually by a competent person. Don't suppose that it is going to run forever after it has first been inspected and sealed up. In fact, the successful use of wattmeters depends largely upon the intelligence with which they are looked after.

PORTLAND CEMENT vs. BONE ASH FOR CUPELS.

H. Roy Stovel.

The use of bone ash for cupels is so universal, that it is with great diffidence one seeks to introduce any other substance in place of it.

Portland cement on first thoughts does not recommend itself to one for this purpose, on account of its hardness when set. Through having had it suggested to me in a chance conversation I concluded to give it a trial, and have had most satisfactory results, finding it equal to and if anything slightly better than bone ash in every way.

The cement cupels being much harder and stronger, will admit of any kind of handling both in and out of the furnace. They can be dropped or even thrown down without any material damage. Neither are they so liable to fracture in the furnace as are the bone ash ones. In twenty experiments I have only found one with a crack in the cup, and that one so small that it was impossible for any bead but a very minute one to fall into it.

The cement being slightly heavier than bone ash with equal absorbing powers, it follows that size for size the cement cupels will absorb more lead, while for ordinary size buttons they may be made shallower, thus enabling one to see more of the cup while in a small muffle, and at the same time a saving is made in material.

As will be seen in the accompanying table the loss with the cement cupels is, in most cases, slightly less than with the bone ash ones, varying for 18 cupellations, of from 2 to 600 mgs. of silver, from nothing to 4.86%.

The relative cost of the two materials, locally, is much in favour of the cement, bone ash costing by bulk 7 cents per lb. while the price of cement is $6.50 at Yellow Union per bbl., being only a fraction of the price of the bone ash.

PORTLAND CEMENT vs. BONE ASH CUPELS.

Results Obtained in Comparative Experiments.

No.	Kind of Cupel.	Weight of Silver.	Time put in F.	Time to clear	Time Finished.	Weight after Cupellation.	Loss in wt.	% Loss.	Time in F.	REMARKS.
1	Bone Ash	$104\frac{27}{60}$ mg	3 22	2′	3 – 38	$102\frac{27}{60}$	2 mg	1.91	16′	Result in favour of Bone Ash Cupel.
2	Portland Cem.	$101\frac{16}{60}$ mg	3 – 22	$1\frac{1}{2}$′	3 45	100	$2\frac{2}{60}$ mg	1.98	23′	
3	Bone Ash	$591\frac{24}{60}$ mg	3 45	4′	4 – 13	581	$10\frac{24}{60}$ mg	1.75	28′	Result in favour of Portland Cement.
4	Portland Cem.	$599\frac{68}{60}$ mg	3 45	$4\frac{1}{2}$′	4 – $13\frac{1}{2}$	$588\frac{38}{60}$	$9\frac{29}{60}$ mg	1.56	29′	
5	" "	2 mg	1 45	6′	2 – 17	2	....	......	32′	Cupelled with 20 gms. lead.
6	Bone Ash	$2\frac{4}{60}$ mg	1 – 45	6′	2 – 18	$2\frac{4}{60}$	....	......	33′	" " " "
7	" "	$3\frac{29}{60}$ mg	1 45	6′	2 – 18	$3\frac{29}{60}$	....	......	33′	" " " "
8	Portland Cem.	$3\frac{42}{60}$ mg	1 – 45	8′	2 – $19\frac{1}{2}$	$3\frac{42}{60}$	....	......	$34\frac{1}{2}$′	" " " "
9	" "	$8\frac{42}{60}$ mg	1 – 45	7′	2 – 19	$8\frac{26}{60}$	$\frac{16}{60}$ mg	3.06	34′	" " " "
10	Bone Ash	$8\frac{42}{60}$ mg	1 – 45	12′	2 – 21	$8\frac{26}{60}$	$\frac{16}{60}$	3.06	36′	" " " "
11	" "	$13\frac{24}{60}$ mg	1 45	13′	2 – 21	$13\frac{18}{60}$	$\frac{6}{60}$	.74	36′	" " " "
12	Portland Cem.	$13\frac{22}{60}$ mg	1 – 45	13′	2 22	13	$\frac{22}{60}$	2.74	37′	" " " "
13	Bone Ash	17 mg	2 – 25	3′	3 – 21	$16\frac{14}{60}$	$\frac{46}{60}$	4.53	56′	" " " "
14	Portland Cem.	$16\frac{50}{60}$ mg	2 – 25	3′	3 – $01\frac{1}{2}$	$16\frac{4}{60}$	$\frac{46}{60}$	4.50	$36\frac{1}{2}$′	" " " "
15	Bone Ash	$9\frac{27}{60}$ mg	2 – 25	2′	3 – $01\frac{1}{2}$	9	$\frac{27}{60}$	4.76	$36\frac{1}{2}$′	" " " "
16	Portland Cem.	$9\frac{31}{60}$ mg	2 – 25	2′	3 – $01\frac{1}{2}$	$9\frac{9}{60}$	$\frac{22}{60}$	3.85	$36\frac{1}{2}$′	" " " "
17	" "	21 mg	2 – 25	2′	3 – 08	$20\frac{35}{60}$	$\frac{25}{60}$	1.98	43′	" " 30 gms. "
18	Bone Ash	$20\frac{51}{60}$ mg	2 – 25	2′	3 – 07	$20\frac{24}{60}$	$\frac{27}{60}$	2.05	42′	" " " "
					Test for	Absor	ption			
		Wt. Cupel.	Wt. Lead	Wt. after Cupellat'n	Gain					
19	Portland Cem.	14.6 gms	25 g	38 220 gms	23.620 gms	being	1.59 tim	es its	own	weight } Both cupels are same size.
20	Bone Ash	13.079 gms	"	31.935 gms	18.856	"	1.44 "	"	"	" }

Summing up and using the results of the few experiments I have made, which, having had to be done in spare moments, are not as many as I would have liked to have done before laying this paper before you, I find results to be as follows:

Time of cupellation about the same.

Loss in cupellation slightly in favour of the cement.

Cement cupels less liable to breakage and fracture in the furnace.

Absorbing power of cement, size for size, greater than that of bone ash.

Cost of cement being only a fraction of that of bone ash.

In sending this paper to be read before you it is in hope that some members of the Society who are interested in assaying may become sufficiently interested in this subject to carry on some more experiments in the laboratory of the school, the results of which I would very much like to know.

N.B.—I neglected to state that the cement cupels are made in identically the same way as the bone-ash ones.

NOTE.—Portland cement cupels have been in use in the assay laboratory of the School for the past three years. In the Spring of 1899, Mr. Mickle, being unable to get a good quality of bone-ash, commenced some experiments with cement, the result of which led to their almost exclusive use in our laboratory. The only drawback to cement cupels is the fact that after they have been brought to the proper temperature they have to be kept thus for from 10 to 15 minutes before putting in the lead, otherwise "spitting" will ensue.—*Editor.*

PEAT.

ARTHUR G. ARDAGH.

Peat or turf, by which latter name it is generally known by those acquainted with it in the old lands, commands an interest to-day from more than one point of view. While you may be interested in it from a scientific point of view purely—a matter for research, if no further, there are those who have been giving many years and much money in endeavouring to devise suitable machinery for compressing it, and thus to place it on the list of successful commercial industries. Expired patents are legion, and for 30 or 40 years we have records of experiments. I can also assure you that there are also many who, with no interest in its manufacture, are waiting to use it in their homes just as soon as it can be procured.

I would not touch upon the commercial side of the question if we were not as engineers specially interested with that aspect, and in fact a constant question is "Can it be made in paying quantities?"

The fascination of the subject and golden hopes of success have ever brought forward fresh brains and resources to fill the breach. Up to this time commercial success has not been attained, but we have good grounds to hope that we are on the eve of it. Although the public hear less of the subject than formerly, there are many earnest workers employed in solving (and I believe they will be successful, if indeed they are not so already) the difficulties of the situation. I think we have crossed the mountains and are descending the foot hills.

Most of us have gathered our hearsay information in regard to peat from old country people. There are deposits throughout Northern Europe in those countries which have sent our fathers and forefathers here. Ever since Caesar's time, at least, the peat fire has been burning.

Here also in Canada there are deposits of a similar nature, for all peats are not alike. If we class decomposed vegetable matters under the general name of peat, we have deposits formed of decayed grasses, sedges, aquatic plants, etc., we have cranberry marshes and pockets of "swamp muck," as it is called, scattered over the country. The farmer is well acquainted with its qualities who has to fight the swamp fire till the snow comes. Speaking of peat, Dana says:

"In temperate climates it is due mainly to the growth of mosses of the *genus sphagnum*. This plant forms a loose turf, and has the peculiar property of dying at the extremity of the roots below, while it continuously grows and increases above the surface, and by this process a bed of great thickness is formed."

It is specially of this kind of peat that I speak. There are two deposits I know well, that of 4,000 acres in Welland County, and a somewhat smaller deposit in Perth County, north of Stratford.

I believe there are a large number of deposits of this sphagnum peat in Canada. There are, I am told, bogs of excellent quality and extensive area in Newfoundland, Quebec and Ontario. There are huge muskegs in the northern part of Ontario, Manitoba and elsewhere, we know, but they are yet to be proved workable deposits. In Ireland beds of great thickness are found in which are embedded and preserved great oaks of a time long since. The peat is cut year by year off the face of the bank left the previous season. The upper stratum of "recent peat" is more fibrous and the colour brown when dry. In "older peat" there are few traces of fibrous matters, and it presents a pitchy hue when cut. It will dry out more or less brown unless it is puddled, when the density increases the dark colour. The upper stratum is called slave turf, because it can be dug with a slave, an instrument like a spade with a wing to enable the bricks of peat to be cut on two sides with one action. The lower stratum is often not cohesive enough to be handled in bricks as it comes from the bog, and this is tramped on the bank and then moulded by hand. It is called mud turf, hand turf, stone turf, or puddled peat.

The output of these operations is, in general, used locally. Most landlords in Ireland have bogs from which they get their

own supply, and the right to cut peat generally goes with a tenant's lease also.

But as to shipping it to a distance, the bulky nature and the dust prevent this being done to any extent. Hence the great efforts made in every country where peat is found to compress it into a more portable and marketable shape.

The process of excavating and drying the peat as performed on the Ellice marsh, north of Stratford, in 1899 and 1900, was as follows: Trenches were staked out 3′ 8″ wide, and at intervals two men, side by side, were set digging with the ordinary steel spades with lifting handles. The peat was dug out one spading deep at a time and spread along the bank, when this was dry on one side it was stacked in small stooks of four or five with the wet sides out, three or four pieces on end and one on top. Subsequently these stooks were gathered into larger piles to make way for the spreading of a second spading and so on. To gather in the dry peat, portable tracks were laid over the ditches and the peat thrown into trams carrying from ¾ of a ton to one ton and conveyed to sheds or huge stacks to be thatched with lumber or moss.

A factory was erected to press the peat, which at present is shut down awaiting the perfecting and trial of mechanical drying, which is occupying the attention of those interested in the enterprise at present.

There are various dryers about to be tested more fully this summer, enough has been done to warrant our hoping we have overcome this crux.

Peat reabsorbs moisture easily, and if spread in a finely disintegrated state on the surface of the bog it will never dry enough to render artificial drying unnecessary

As to its burning qualities, peat ignites easily, requires practically no draught when once the fire has taken hold, gives intense heat, and a banked fire will not burn out nor will it go out until the fuel is consumed. It burns with a flame for some time, and then for a longer period in red hot coals. The gases emitted in the initial stages of burning are not only innocuous but considered by some medicinal, especially against lung troubles. The percentage of ash will vary with the deposit from which the peat

is taken. The following analysis was made of samples of compressed fuel made from the product of the Welland bog with the moisture reduced to a suitable amount:

Moisture	12
Volatile matter	58.20
Fixed carbon	26.
Ash	3.80

The absence of soot, clinkers and practically of smoke (when burned under proper conditions) are qualities which will appeal to all classes of consumers. Peat in its crude state varies very much in weight—about 600 lbs. to the cubic yard may be taken as a fair density. The fuel as consolidated by the Dickson press will weigh from slightly under soft coal to slightly over hard coal, neither frost nor a damp atmosphere will affect it, but it should be protected from rain.

In the Dickson press the peat, after being broken to a powder in a breaker, is disposed automatically by gravitation towards the lower and stationary dies or moulds, which consist of two steel tubes about twelve inches long, of uniform bore and open at both ends, into which work two punches. Each charge of peat which flows in when the punch rises is compacted into a solid block on the top of the previously made blocks which occupy the lower two-thirds of the tube, and this column of blocks is forced down a distance equal to the depth of the block made, and thus each time one drops out at the bottom. The resistance thus obtained is yielding. Processes which involve the consolidation of the crude peat in a wet or hot state leave it subject to disintegration upon drying or cooling.

To dry peat in the air it must be exposed to the wind in brick form, and never more than 4 or 5 inches thick whatever length and breadth it may have. It will never dry in heaps or in powdered form either, unless it were spread an inch deep on boards, which is practically out of the question. Air drying may be done on racks, but the initial cost of the racks will be large.

I believe that in such a situation as the Ellice bog, where my own plant is situated, that the peat can be easily harvested after air drying with only 25% of moisture. This would make the

task of reducing the moisture another 10 or 15 per cent. by artificial means an easy one.

It is proposed by some to squeeze the first 30 or 40 per cent. of moisture out of it, and for this purpose an hydraulic press has been set up at the Trent Valley Peat Fuel Works. Fresh peat contains from 75 to 90 per cent. of water, which shows what an amount has to be handled to secure one ton dry weight. The time of drying varies with the weather, the handling it gets, and the artificial shelter, if any.

It might dry in a month easily, but count on six weeks on the average.

In well designed plants an endeavour will be made to eliminate hand-labour as much as possible. The plant will cover quite an area of ground, but the storage building will be inexpensive. They will be all connected with conveyors.

Dredging machinery will be used in some bogs, in which case the peat will be squeeed and artificially dried, and what takes now six weeks will occupy less than an hour.

THE CONSERVATION OF WATER FOR POWER PURPOSES.

C. H. Mitchell, B.A. Sc., C. E., A. M. Can. Soc. C. E.

In Canada and particularly in the Province of Ontario where the wealth of water powers is known to be almost inexhaustible, the study of conservation of water for power purposes seems almost superfluous. Conditions, however, frequently arise where the concentration of water at one point from a limited area becomes highly necessary for commercial purposes.

The following paper was prepared in the form of a report, made in October, 1900, for a well known mining company in Ontario, and with their consent the writer has arranged it for the Engineering Society in the hope that it may provide information on a subject upon which but little has appeared in the Society's publications.

The circumstances leading to the examination of this hydraulic proposition required that sufficient water be provided from a very limited area, for the present small experimental plant, and ultimately for a proposed plant of large capacity. The grade of the ore in this locality was such as to render it preferable to develop direct power at this point even at considerable expense for the collection and storage of water. The power is required for running a crushing and washing plant in the process.

General.

1. The mine now worked by your company is situated on Lot 3, Con. xviii., Township of Raglan, with the present mill situate on Lot 2, about a mile distant by road. These works are about 6 miles south of the Village of Combermere, and 20 miles south from Barry's Station on the Canada Atlantic Railway. They are at an elevation of about 200 feet above, and a mile west from the York River, which is a considerable stream tributary to the Madawaska River, the junction of which is about 4 miles north from the mill. This will be seen by reference to the "General Map" accompanying this report.

2. Access is had to the works from Combermere at present by road only, the country being very hilly, and the roads for the

most part rough, though improvements have been lately put on them. Transport can be effected by water via the Madawaska and York Rivers to a point within about 1.5 miles of the works, from which a road is now being constructed. This water is available for 8 months of the year through to Barry's Bay, where a spur track is in contemplation to the wharf.

3. The mill is situated upon a small creek known as Long Lake Creek, and was formerly a small saw-mill, and is supplied with water for power from the creek by means of a small dam. This creek has its sources to the west, and above the junction in the "Menzie Meadow," about 2 miles distant, trends from the north on the one hand from Long Lake (about 200 feet above the mill), and from the west, from a series of small lakes and meadows fed by a considerable area of hilly district. The latter branch is known as Lennon's Brook. At the extreme end of this is a small lake or pond which is called Summit Lake, about 150 feet above the present mill, the waters of which flow westward, though in wet season much of it would come east. This appears to be fed to a large extent by the country to the north.

At a point about 0.75 miles west of the mill, Robilliard's Brook enters the Long Lake Creek. This drains an area in a pocket among the hills in which is a small pond called, by settlers, the Beaver Meadow, some 200 feet above the mill.

To the north-west of Long Lake lies Echo Lake, at an elevation of nearly 400 feet above the mill, which, though of larger area than any lake in the vicinity has a comparatively small drainage area, the water from which flows by Round Lake and outlet to the Madawaska to the north and away from Long Lake.

The greater part of the drainage area outlined above lies in the Townships of Carlow and Bangor, smaller portions being in Raglan and Radcliffe.

4. The general nature of the country is very hilly, with areas of lake marshes and low ground lying between. The hills rise to a general height of about 500 feet above the valley of the Long Lake, and Lennon Brooks, and lie in an irregular position rather than in any particular direction of ridges, a fact which is

favorable for water supply, and storage. The slopes and crests of the hills are covered to a considerable extent with hard wood and second growth brush. The valleys are more or less open, with patches of second growth.

5. The prevailing temperatures in this locality are extreme, the summer average being at times as high as 90 degrees F., and the winter as low as — 30 degrees F., frequently much lower. This is a considerable factor in water supply owing to the evaporation in summer, and the freezing of springs, watercourses, and rainfall in winter.

Rainfall, Sources and Storage.

6. The most essential feature in the supply of water from this locality for power is the available rainfall. Having examined the streams during the first week in October of this year, the writer was able to determine the average fall flow of water available, a part of which, though small in quantity, may be termed "ground water" rising from springs, and quite independent of the rainfall. The rainfall source of supply appears to be variable from year to year, and even by monthly comparison.

The nearest meteorological observing station to this locality is situated at Renfrew, about 45 miles to the east as the crow flies. Observations on rainfall have been carried on at this point since 1884, though at times they have been omitted, and there are some readings which there is reason to doubt. Below is a table showing the totals of annual rain and snow fall equivalents in inches. Observations in the years not shown are incomplete:

	Rain.	Snow.	Total.
1884	13.54	8.60	22.14
1885	16.56	11.48	28.04
1886	19.00	7.35	26.35
1888	13.19	4.35	17.54
1889	23.26	7.87	31.13
1890	17.15	6.70	23.85
1891	21.14	4.71	25.85
1893	22.71	2.76	25.47
1894	13.20	1.75	14.95
1895	9.13	4.47	13.60
1897	13.50	5.20	18.70
1898	19.67	6.45	26.12

The abnormally low rainfall in the years 1894 and 1895 is evidently due to incorrect readings, as an examination of the records would lead one to suspect. Omitting the observations of these two years, the average of 10 years, as above since 1884, is a total fall of rain and snow combined of 24.52 inches, while, including the two years mentioned, it becomes 22.81 inches. The year 1898, being the nearest to the average in recent years, is given below so as to illustrate the monthly variation, although the months September and October are abnormally high:—

Year 1898.

	Rain.	Snow.	Total.
January	0.00	2.00	2.00
February	0.00	1.80	1.80
March	0.62	0.00	0.62
April	0.47	0.10	0.57
May	2.51	0.00	2.51
June	2.87	0.00	2.87
July	2.15	0.00	2.15
August	2.05	0.00	2.05
September	4.09	0.00	4.09
October	4.91	0.00	4.91
November	0.00	0.80	0.80
December	0.00	1.75	1.75
Totals	19.67	6.45	26.12

The average month by month covering the typical years 1885, 1886, 1888, 1890, 1897 and 1898, is given in the following table, which shows the rain, snow and total for each month.

	Rain.	Snow.	Total.
January	0.44	1.25	1.69
February	0.16	1.38	1.54
March	0.32	0.91	1.23
April	0.95	0.95	1.90
May	1.61	0.02	1.63
June	2.70	0.00	2.70
July	2.40	0.00	2.40
August	2.65	0.00	2.65
September	1.85	0.00	1.85
October	2.13	0.04	2.17
November	1.01	0.68	1.69
December	0.13	1.64	1.77

This by inspection would lead to the assumption that while the "dry weather" season occurs in the winter months the precipitation is fairly constant throughout the year, that is to say that the July, August, September and October weather so frequently known as "dry" produces quite as much rainfall as other seasons, and that if there is any shortage of water it is caused solely by evaporation and absorption. The northern country is well known to give a "dry weather" season in March, a fact which is borne out in this locality by the last table, the precipitation being nearly all snow water.

The inference from these tables is that generally speaking the "dry weather" occurs not in the summer or fall, but in February and March, during the extreme cold weather, and that conservation of water must look toward that season and not so much toward the warm summer season.

7. The character of the country has much to do with the securing of rainfall water as under any circumstances a certain portion of the water is lost, the amount depending upon the general inclination of the slopes, and the character of the soil, etc. Flat country and very gentle slopes give a less percentage of the total rainfall capable of being collected and stored, than does steep, hilly and rocky country. This amount of water reaching the basins or streams is termed "run-off." By an examination of all the conditions in the areas for supply for your purposes the writer does not think it wise to assume the run-off in excess of 50%, which is a moderate and conservative figure for such country. The remainder of the precipitation would be lost through evaporation, absorption and seepage into underground channels.

Assuming as an average annual precipitation for calculating purposes the amount of 24 inches, the run-off can be safely assumed as 12 inches of rainfall per annum. Twelve inches of water over one square mile of area would produce about 27,880,000 cubic feet of water.

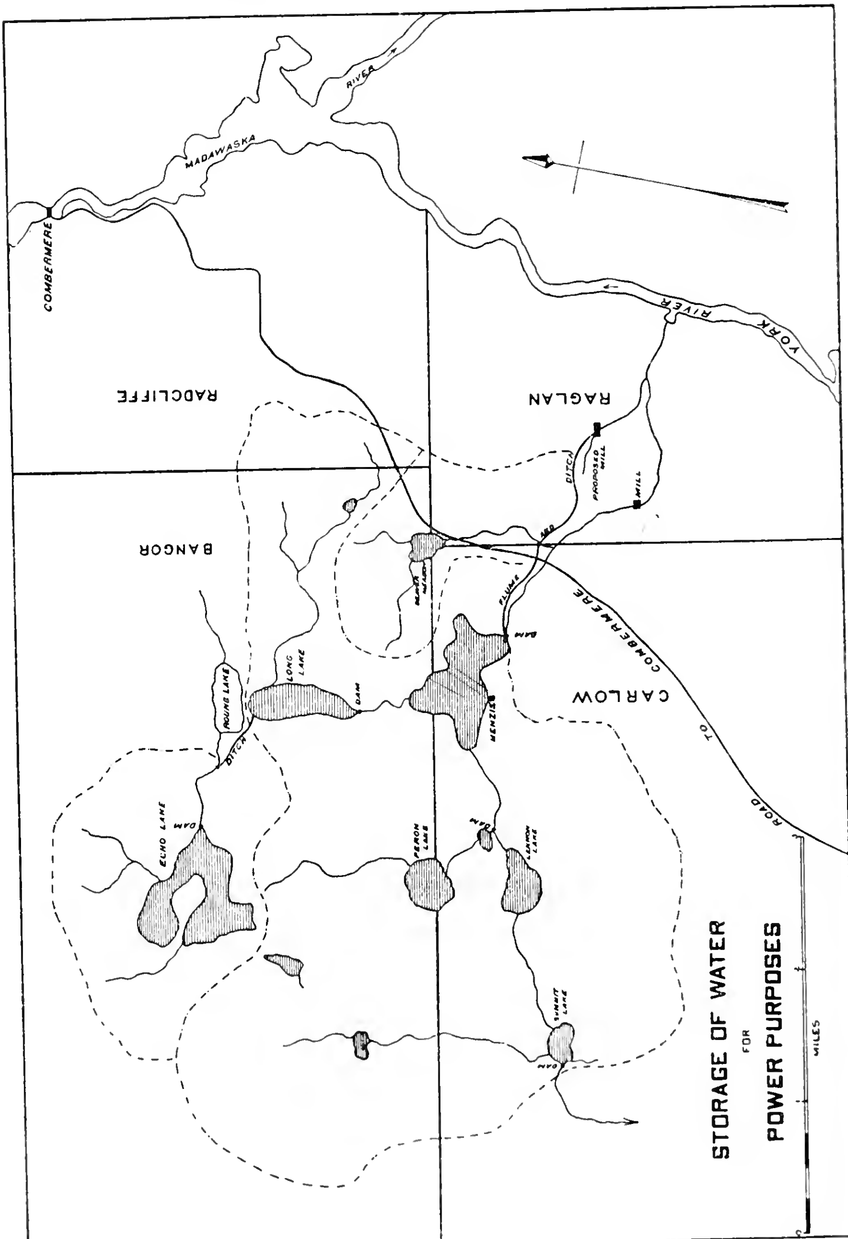
8. The main area as shown on the general map of the supply, comprising Long Lake with its tributaries, and the Lennon Brook, etc., comprises about 13.0 square miles. Within this area there is about 0.65 square miles (5%) or 435 acres of water surface

at ordinary times, *i.e.*, including lakes, streams and marshes. Long Lake has an area of about 90 acres, at its present level. The area of thirteen square miles should produce about 362,000,000 cubic feet of run-off water per annum. The writer estimates the ground water as indicated by the October flow at about 48,000,000 cubic feet per annum, thus bringing the total water available in the main water shed area to a flow of 410,000,000 cubic feet per annum.

By an examination of the average monthly rainfall for many years back, and having regard for the snow, ice and spring freshets, together with an assumed constant ground water flow, estimated approximations for the total monthly flow from this area have been made. These lead one to believe that the average flow during the months of December, January, February and March, will not exceed say 11 million cubic feet per month, and might at extremely cold and dry seasons run as low as 8 million cubic feet. April, May and June might be assumed at an average of from 50 to 70 million cubic feet per month, the other months of the year being from 20 to 40 million cubic feet.

9. The area shown by the general map comprising the "Beaver Meadow" and Robilliard's Brook drainage, gives about 1.5 square miles, of which about 25 acres ($2\frac{1}{2}\%$) is water surface. Springs in this locality are numerous, and these, together with the rainfall, it might be estimated would give about 46 million cubic feet per annum. This would produce monthly about one-tenth the amounts shown for the general area. The greatest part of the water from this area reaches the Long Lake Creek at a point about ¾ miles above the mill.

10. The Echo Lake area lies high above the previous water sheds, and consists of a drainage of about 3 square miles, of which 250 acres or 10% is water surface. This lake is fed largely by springs, and the slopes are comparatively short and steep. This area should produce with the ground water a total flow of about 100 million cubic feet per annum. The cold weather winter flow should not be less than about 2 million cubic feet per month, the maximum spring flow for three months about 15 to 20 million cubic feet per month, and remaining average about 7 to 10 million cubic feet.


STORAGE OF WATER
FOR
POWER PURPOSES
MILES
MADAWASKA
RIVER
YORK
RIVER
COMBERMERE
RADCLIFFE
RAGLAN
BANGOR
CARLOW
COMBERMERE
TO
ROAD
DITCH
PROPOSED MILL
MILL
FLUME
DAM
LONG LAKE
ROUND LAKE
DITCH
ECHO LAKE
DAM
MENZIES
PERON LAKE
LEMON LAKE
SUNNIT LAKE
DAM

Present Mill and Plant.

11. The present mill is situated in the gorge of the Long Lake Creek, immediately below a log and earth dam, about 15 feet in height. The dam was originally built for a saw-mill and was increased in height and strength for the present mill. This impounds water to only a small extent of surface as the creek inclination is somewhat steep. Water for driving the mill is drawn from the dam by means of a 15 inch spirally rivetted pipe to a point about 300 feet below the dam, where power is generated by a 37 inch "Cascade" impulse wheel, with five nozzles, under a normal head of about 44 feet, variable on account of head water; at this head the wheel gives about 39 horsepower. This plant has been in operation only since July, for experimental purposes.

At the time of the writer's visit (October) this wheel was developing about 30 horsepower, and was using about 7 cubic feet of water per second when all machinery was on. The heavy crusher machinery was running at that time only about 4 hours per day out of the 20 hours run, using about 15 horsepower, and the remainder of the time the lighter machinery used only about 15 horsepower, with 3.6 cubic feet of water. The ore treated in the mill was about 20 tons per day of 20 hours, and observations made on the performance of this experimental mill show that it requires about 1 horsepower per ton of ore treated for all purposes, although this should be considerably decreased by improvements which can be made.

12. Measurements of water coming down to the mill show that under normal conditions in October as indicated above, about 5 cubic feet per second of water was being used for all purposes, washing, leakage, and other loss. The latter can be saved by careful attention to the dam, which is now being done.

A series of measurements extending from May 17th to July 12th, 1900, on the water flowing over a 70 inch weir at the mill gives an average discharge of about 60 million cubic feet per month. During this interval, however, a dam was placed in the outlet to Long Lake on June 4th, thereby cutting off supply from that district. Previous to this date the average for the 18

days in May was at 26 cubic feet per second, or at the rate of about 70 million cubic feet per month. This figure includes the Robilliard area, but does not include the water from the west end of the main area, which it is contemplated to bring to the mill. Though the rainfall at Renfrew for the first five months of 1900, and for the month of May, shows about 25% greater than the average for the periods, as indicated in paragraph 6 above, nevertheless the above discharge as measured appears to agree with the run-off production indicated in paragraph 8. After the dam was placed in Long Lake the rate of flow for 38 days in June and July was 20 cubic feet per second, or about 53 million cubic feet per month, during which time Long Lake was filling according to subsequent measurements at the rate of about 5 million cubic feet per month. These figures also appear to agree fairly well with the previous deduction from the rainfall and run-off.

13. There is no doubt whatever that this flow of 5 cubic feet per second as measured cannot be maintained throughout the winter months or during a particularly dry season in the fall. This is shown by the fact that the present plant has been drawing to a small extent this year upon the Long Lake reservoir since August 24th. This lake was dammed on June 4th by a small dam and allowed to fill until the former date to a height of about 30 inches. Since that time water has been drawn from it at the rate of about 0.7 to 1.0 cubic feet per second, of which from 0.4 to 0.5 cubic feet is storage water.

While a minimum of water of about 5 cubic feet per second will be required to be maintained during the present winter, a greater amount, about 8.0 cubic feet per second will be required next year in view of the contemplated enlargement of the present experimental mill, when a wheel of greater power may be installed. A 50 horsepower wheel could be run with this water on the same principle as at present, running all the machinery at full power about one quarter of the time, and the lighter machinery at about 20 horsepower during the remainder.

PROPOSED FOR PRESENT PLANT.

14. The present dam will require to be carefully overhauled and strengthened so as to ensure its security and close the leaks.

The stability of this dam is most essential, as the mill is situated immediately below it. The immediate construction of a sufficient spillway through the dam to provide for the spring freshets, is advisable, the former wasteway having been closed, and it would be well also to clear the mill pond of brush and logs, etc.

15. The chief problem for the present plant is to provide the supply of 8 cubic feet of water at the mill the year round. To do this requires the utilization of storage areas sufficient to store water to supply the deficiency in the dry and cold weather months, viz., December to March, inclusive, and possibly October and November at times.

The writer is of the opinion that the main area, together with the Robilliard area, as before indicated, will provide sufficient run-off water to do this, and that storage reservoirs in the Menzie Meadow and on Long Lake can be suitably arranged to store water for the dry seasons.

Assuming that the minimum dry season produces by the run-off from these two areas 8 million cubic feet per month for the four winter months, December, January, February and March, and 18 million cubic feet per month for October and November, which is a conservative figure, the storage areas must supply the deficiency up to the 8 cubic feet per second limit. The amount of water required by the mill at this figure running 24 hours per day, 31 days in the month, will be approximately, 22 million cubic feet per month. Consequently the draft on the storage areas would be 14 million cubic feet per month for the winter months and 4 million cubic feet for October and November. That is to say a total of 64 million cubic feet would be required, without considering losses by evaporation, freezing, absorption, etc.

16. To provide for this, dams for storage will be required at the outlets of the Menzie Meadow, and Long Lake.

The Menzie Meadow dam is proposed at the point shown in the plans, and should be built so as to impound water to an elevation of 185.0 feet above the datum of levels as per the contour plan, or about 14 feet above the level of the creek immediately above the outlet. This dam can be built of logs, earth and stone, which can be easily found in the locality. Its extreme height

would be about 17 feet and its length about 200 feet, at the located site, assuming the water to be within a foot of the top at high water, the crest of the dam being at elevation 186.0. This dam should be made perfectly tight and with a spillway to provide the passage of high water in the spring. It should have stop logs or a gate so arranged as to deliver the required amount of water over and into the creek bed. The amount of water delivered will not need to be as much as 8 cubic feet per second as the Robilliard stream and springs in the valley will provide a portion of the water required for the mill.

The Menzie Meadow thus dammed so as to raise the water to an elevation of 185.0 would provide for a storage of about 83 acres, which, with the dam arranged so as to draw off the upper 13 feet of the pond, would store about 46 million cubic feet. The evaporation and absorption during the summer months, together with temporary loss in the winter by frost, should not exceed about 20% of the amount if the brush and trees, particularly within the upper pond area, are cleared so as to reduce the evaporation to a minimum. The writer is of the opinion that a storage of 37 million cubic feet can be considered as reliable for this reservoir, at the height of dam indicated. Should more water be required at any time in the future, it can be impounded by raising this dam a few feet; the dam might be built with this in view.

It appears from the precipitation that there will not be sufficient rainfall this fall and winter season (1900-1901) to provide any water for storage above that now being used, but the immediate construction of this Menzie dam is advisable, so that when the spring thaw and rains set in the reservoir may be filled by the flood water. This water will then become available in the fall and winter of 1901.

The dam placed at the outlet of Long Lake in June, 1900, serves to raise the water about 2.5 feet. If this were raised so as to impound water to a depth of 10 feet above the old lake level, a storage of about 42 million cubic feet would be secured. Deducting about 20% as before, for evaporation, etc., about 34 million cubic feet would be available. This is quite feasible and its construction during the coming winter is also advisable to

secure the flood water in the spring. The area draining into Long Lake is not large, and would not be sufficient to fill the pond as proposed unless the outflow were shut off entirely. This, however, can easily be done, as the surplus water from the western portion of the main area, coming to and over the Menzie dam would be sufficient to run the mill. With a properly constructed dam and excavation the water of Long Lake could be drawn down even lower than originally.

17. For the demands of the coming dry winter season, before these dams fill, steam power will be required if the mill is to be kept running. Under the present circumstances a 15 horsepower steam plant ought to be quite sufficient as an auxiliary to the water plant with what water comes down. This can subsequently be used for heating and other purposes.

The following is a recapitulation of the works proposed for improving the present plant:—

1. Strengthening present mill dam, stopping leaks, constructing spillway, and possibly ultimately raising crest.

2. Possible ultimate installation of larger wheel and feed pipe, for say 50 horsepower.

3. Building Menzie dam, and clearing area.

4. Building Long Lake dam.

Water provided—8 cubic feet per second.
Available water stored—71,000,000 cubic feet.

Proposed New Mill.

18. There is in contemplation, the construction of a new mill at the location shown on the plans, of much greater capacity than the present experimental mill, if the construction is justifiable by circumstances. Such a course would entail the abandonment of the present mill, and the use of the machinery and the water for the new plant. The following hydraulic considerations are upon this basis.

19. As has been previously shown the total water available from the three drainage areas is constituted of: main area, 410 million cubic feet per annum, Echo Lake area 100 million, and Robilliard area, 46 million, a total of 556 million cubic feet. Of

this, by a conservative estimate, more than 80% could be utilized for the mill, or say a maximum of 444 million cubic feet, a monthly average of 37 million cubic feet. This is at the rate of 14 cubic feet per second used constantly.

It appears from previous figures that the dry weather flow for the four winter months will not exceed 11 million cubic feet per month from all sources; and that the months of October and November cannot be depended upon beyond 25 million cubic feet per month. Hence a deficiency of water under the requirement of 37 million cubic feet per month, occurs in six months of the year, the draft for the four winter months being at the rate of 26 million, and for October and November 10 million, a total deficiency for the year of 124 million cubic feet, without considering evaporation, etc.

20. The proposed location of a new mill of large capacity, as shown on the plans, is in a ravine immediately below the mine. The advantages of this location are evident. Ore can be sent direct to the mill by gravity, with a short haul. A very high head of water can be secured, and transport for produce easier. A possible advantage is its location out of the line of discharge from the country above, should any of the storage dams go out.

As shown by the map, a mill could be constructed with a water wheel at elevation about 20.0 feet above datum. As previously shown, the elevation of the surface of the storage reservoir at Menzie's already proposed, about 2 miles distant, is 185.0, a difference of 165 feet. This head of course could not all be utilized, as it is proposed to draw the storage of the Menzie reservoir down to elevation 172.0, and as about 18 feet head will be lost in bringing water down the valley, thus leaving an available head on the wheel of 134 feet. Fourteen cubic feet of water per second as is shown above appears to be the maximum which with close regulation can be depended upon as a supply from the areas. This amount of water with 134 feet head would provide 180 horsepower on the shaft for the new mill, running constantly.

Proposed Works for New Mill.

21. The proposition of securing such a large percentage of the total available supply from the areas and storing say 150

million cubic feet (124 million to be available), though quite feasible, will require the utmost attention to construction and regulation to ensure success. The sites for storage are four in number, as follows:

(1) Menzie Meadow. As before proposed, with a dam, however, 5 feet higher, at which level it is estimated 66 million cubic feet can be stored above elevation 172.0, of which, after deducting 20% for evaporation, etc., 53 million cubic feet should be available.

(2) Long Lake. As before proposed, at same elevation, and capacity, viz., 34 million cubic feet.

(3) Echo Lake. By means of a dam at the outlet of Echo Lake, 6 feet in height, 66 million cubic feet could be impounded in the 250 acres extent above the present level. Deducting from this the 20% for evaporation, etc., as before, there would be 53 million cubic feet available water.

(4) Perch Lake. A small storage reservoir can be made in this locality by the construction of a dam at the outlet to its waters. This dam at a height of not more than 10 feet will impound at least 24 million cubic feet, or say 20 million available, though it would not be necessary unless difficulty were found in filling the other reservoirs, or it might be built instead of raising the Menzie dam. It would also be found difficult to fill a dam at this point if water was also being impounded at Menzie's, as the 14 cubic feet flow to the mill must be maintained.

A small storage reservoir could also be made available at the Beaver Meadow, though it is a question if it would be wise or would pay, as the road would require to be moved east up the hill, at considerable expense.

No doubt difficulty will be found in securing the storage of these waters simultaneously, while at the same time maintaining the adequate supply to the mill. This can be arranged only by close regulation of the discharge through the different dams in the spring.

22. A small dam will be required at the western outlet of Summit Lake, so as to turn its waters eastward, also the eastern high water outlet improved and deepened through the marsh.

23. The means of getting the available water to the mill will require considerable work, and comprises the main part of the expense of the project.

Echo Lake lies nearly 200 feet above Long Lake, the brook outlet being very rapid, and falling into Round Lake some 23 feet below the level of Long Lake. Consequently to secure the waters of Echo Lake for power purposes, a conduit will be required from some point on this brook such that the water may be carried over to Long Lake. The proposed location of this is shown in the general plan, and is about 2,400 feet in length, following around the base of the hill which is more or less rocky. This will necessitate the construction of a small flume rather than of a ditch, although part of it might be ditched. A ditch or flume of about 2.5 square feet wet cross section should be sufficient with the grades. The water may be caught at the Echo Lake Brook by a small log dam at the outlet of the lake above. The construction of the latter dam is recommended at least a year before its water will be required.

The Menzie dam being the lowest point on the storage areas, should be specially arranged with regulating gates, easily operated. Irrespective of the level of the water in this reservoir its discharge should at all times be delivered to the head bay immediately below the dam at an elevation of 172.0 so as to provide the drawing out of all the water above the dam. From this point to the proposed forebay above the mill is about 9,400 feet, following the course of the proposed flume and ditch line as shown on the contour plan. This conduit is proposed at a grade throughout of about 0.20% or 1 foot in 500, with a wet cross section of about 6 square feet; in ditch, in earth and gravel the water would be about 18 inches deep, the bottom width 2 feet and slopes 1 to 1½, while in flume the width could be 3 feet and depth of water 18 inches. These dimensions would discharge 14 cubic feet per second at the mill.

There are at least two points where the water will require to be carried by flume, viz., at Robilliard Creek, and at the ravine to the east. There will be other points also where it may be cheaper to flume than blast rock. It may be assumed that of the 9,400 feet total length, 1,200 feet would be flume.

Under this plan the waters of the Robilliard area will require collecting at a point above the flume line, and to be led by a small ditch or flume to the main line. This could discharge constantly.

The proposed ditch line will intercept all water coming to it from the hills to the north, but cannot secure water coming to the present creek bed from the south. This water would be but little, but could be caught at the present mill dam and might be utilized in some manner.

When this ditch is cut through sandy or loose soil, or in loose rock, it should be lined with clay or clayey gravel to make it tight. Difficulty will no doubt arise in any case for the first year or so by this absorption and loss by leakage, but as the ditch gets silted up this will disappear.

24. The works at the forebay on the side hill above the mill should be of sufficient size and capacity to regulate the flow of water through the penstock, deliver the surplus over a spillway, take care of ice, brush, leaves, etc. The penstock to the mill should be 24 inches diameter steel pipe riveted, and should be anchored down the slope to the mill.

A difficulty arises in regulation of the water supply to the penstock at the forebay. The supply coming down the ditch must necessarily be constant unless partially shut down for more than a few hours, consequently provision must be made for the spillway of surplus water. This can be done either at the forebay or at the mill. If at the mill its value is lost unless it can be utilized at periods when it is discharged as surplus. It is recommended then to provide a small reservoir in the ravine above the mill, providing a head of say 60 to 80 feet, into which surplus water of a few hours shut down or slack discharge can be spilled. This can be done by a small dam at slight cost. The water from this can be carried down to the mill and utilized for the washing processes and other work, perhaps to run the lighting.

The power at the mill can be developed by an impulse wheel, such as either the Cascade, Pelton or American Impulse, with two or more nozzles, upon the number of which the size will depend.

The tail water can be disposed of without difficulty as there is a good fall to the York River.

25. The following is a recapitulation of the proposition for the new mill:

Water provided—14 cubic feet per second.
Available water stored—140 million cubic feet.
Working head—134 feet.
Available on shaft—180 horsepower.

FINAL.

26. It has been found that as the timber is cut off and the country cleared near the sources of streams, the yield of water decreases. This affects the run-off as the evaporation is more likely to increase. In the present instance, however, it is not expected that the general conclusions would be affected, as the district cannot be said to be heavily wooded, and the water coming down more readily in the spring would be caught by the dams.

27. The advantage of having the mill near the present deposit of ore, which is the best of those owned by the company, is considerable, and if a new mill of large capacity were built in the proposed location, no risk will be run with regard to the power. If some years hence it were found that the available water collected from all sources failed to a serious degree by climate changes in rainfall, or by the clearing of land, power can be obtained by electric transmission from sources elsewhere.

The writer understands that a considerable power is available at Palmer's Rapids, on the Madawaska, 6 miles below the mill, and that other powers now owned by the company exist 20 miles up the York River, distances which are quite feasible for electric transmission. These powers will no doubt be developed in the near future in any case, for other purposes, such as for mining and electric railway, which is already talked of in the locality to connect with railroads to the south.

SOME NOTES ON GREATER ONTARIO.

E. V. Neelands, '00.

In attempting a description of the vast country to our north, which has been not inaptly termed "Our Northern Heritage," the writer proposes to confine himself exclusively to the more unknown portion, north of the "Great Divide," between the waters flowing south to the St. Lawrence system, and those draining into Hudson's Bay, whose southern boundary is roughly determined by the Canadian Pacific Railway. The enormous extent of this territory precludes anything in the nature of a thorough investigation in a paper of this character, and necessitates a statement rather than a discussion of the facts. I will, therefore, endeavour to present in as brief and concise a manner as possible, an account of the district, its nature and resources.

Regarding the region from a geographical standpoint it may, like ancient Gaul, be divided into three parts. Roughly parallel to the C. P. R., a rocky belt traverses almost the entire district from the Ottawa river to the Manitoba boundary. To the north of this in the eastern portion, a clay area, in shape, a rough triangle, extends from Temiscamingue and Abitibi to the Missanabie river. Arable land also occurs in the valley of the Kaministiqua river to the west of Thunder Bay, and in several parts of the Rainy River District. From the northern boundary of the clay land, which in the Moose river basin coincides roughly with the northern limit of the Archean rocks, to the bay, lies an enormous swamp area, practically devoid of timber except small scrubby spruce and tamarac, and underlaid by palæozoic rocks of Upper Silurian and Devonian age.

The northern boundary of the rocky belt follows the eastern bank of the Montreal river from Lake Temiscamingue, and crosses the Nipissing-Algoma boundary line at a point about one hundred and twenty-four miles north of the C. P. R. It then is roughly

traced by Niven's Base Line Lat. 48° 27′ 54″ to the Missanabie river. Here it bends to the north and areas of clay occur on the Ka-hina Kagami and Kenogami rivers to the west, whose southern limits probably represent its continuation. Farther to the westward rocky country generally prevails to the Rainy River District. Rocky areas also occur farther north in some parts, the most important being a ridge of considerable elevation forming the Height of Land between the Abitibi and the water flowing south to the Quinze. The principal formations in this district are the Laurentian and Huronian, widely spread throughout the whole region and consisting mainly of gneisses and green schists, and the Animikie or Nipigeon series in the vicinity of Thunder Bay. Cambrian rocks occur to the north-west of Sudbury, and a small area of Niagara Limestones and Dolomites is found to the north of Lake Temiscamingue and on some islands in the same lake.

It is in this region that the economic minerals, and to a large extent the timber of Greater Ontario are to be found. Valuable finds of iron, nickel, copper, zinc, gold and silver, all of which are mined farther south, are reported from the northern portion of the district, but as little or no work has been done up to the present time nothing very definite as to the extent of the deposits can be said except that the most promising surface showings occur in many parts.

The timber of the district is a less doubtful quantity. White and red pine occur up to Lake Abitibi in the east, but nowhere else east of Lake Superior is it found so far north. In the Rainy River District it is abundant in the south, and is found sparingly as far north as Lac Seul. Banksian or jack pine, white and black spruce and tamarac, poplar, balm of gilead, white and red birch and cedar occur everywhere throughout the district, jack pine being usually found on the sandy ground, spruce and tamarac in wetter country, and the others along the banks of rivers. Fire has played great havoc in the timber of this district, especially in those parts adjacent to the railway, and unless the trees are protected by nature in some way they are usually burned before maturity.

The northern limit of the clay belt cannot be well defined, as it is impossible to draw a sharp line of demarcation. Good land is

found generally as far north as Lat. 49° 15′, on the Nipissing-Algoma line, beyond which it gradually merges into muskeg. Farther north small areas of arable land occur, usually in the neighbourhood of rivers, but generally the country is unfit for cultivation.

Everywhere in this district the common garden vegetables, potatoes, cabbages, cauliflowers, etc., mature without difficulty. Every Hudson's Bay Post has its garden, and the officers of the Company raise with little trouble such green stuffs as they require. Except in the Temiscamingue and the Rainy River Districts, cereals have not been seriously attempted, but there is no reason to suppose that in the southern parts of the country they could not be cultivated with as much success as in districts to the west in the same latitude. Barley has been grown at Moose Factory, but its ripening cannot be depended on as severe frosts frequently occur early in the autumn and sometimes even during the summer months. Farther south the crops would be much safer, as low temperatures are the exception rather than the rule. In the past summer the thermometer did not fall below the freezing point from June 1st to Sept. 8th in the region north of Lake Superior, and I was informed by the officer in charge of Long Lake House, which is situated about eighty miles north of Jackfish Bay, that it was a fair average summer as far as the temperature was concerned.

The timber in this region is similar to that further south, being mainly spruce, tamarac, jack pine, poplar, birch, balm of gilead and balsam. The trees sometimes attain a diameter of thirty-six inches but the average of the larger sort is not above fifteen. The country has been burned everywhere except near water and the second growth is very thick, so that the majority of the trees have not an opportunity to mature. Along the rivers and on the lake shores the timber is larger but has a tendency to be very knotty and twisted.

North of the clay region the country becomes more swampy and finally merges into open muskeg, often as bare as the prairies of the west for many miles, the only break in the landscape being a few clumps or ridges of small stunted spruce and tamarac. The surface of the country is covered with moss many feet thick, which

often stretches across large areas of water, lying on its surface like a blanket and quivering under every footstep. Dry land seldom occurs except in the immediate neighborhood of running water, where clay banks rise up like dykes and separate the rivers from the swamp. On these banks the only large timber is found, usually in a belt not over a few chains in width and frequently even less. In many cases, where the river banks are upwards of thirty feet above the water, open muskeg occurs within a hundred yards of the stream.

In the spring the rivers, whose water volumes are subject to enormous variations, often overflow the banks, and during the dry season the extreme flatness of the country prevents an adequate drainage. This, in addition to the water formed by the snow melting over such large areas, largely accounts for the swampy nature of the country.

The character of the rivers alters greatly immediately upon entering this region. In the south they are usually swift flowing streams with abrupt descents over ledges of rocks, but in the great muskeg district they cut wide channels for themselves, since the erosion of the soft banks is much more rapid than that of the bottom—which is usually flat-lying limestone strata. As a result the great rivers entering James' Bay have strong heavy currents and are wide but very shallow. The Moose at the mouth is about two miles in width, but the depth is seldom greater than a few feet; and the Abitibi can be crossed on foot in places where its width exceeds half a mile. No portages occur on the Abitibi for about 50 miles from its junction with the Moose, and the navigation of the Moose is uninterrupted for considerably over a hundred miles, and that of the Albany for over two hundred. Numerous smaller streams show similar characteristics, which demonstrates the flatness of the whole region. These rivers are all very sensitive with regard to water volume. Nominally the streams flow over flat-lying rocks and have sloping banks covered with alders and "blue joint," crowning the banks are fringes of timber, which mark the high water level, usually many feet above the stream in the autumn. At New Port, about one hundred miles up the Abitibi, accurate measurements showed the spring level of the water to be thirty feet above the river in September.

The only minerals of economic importance in the district are gypsum and lignite coal. The former occurs in large quantities on the French river, a tributary of the Moose, and also on the Missanabie, and a bed of the latter crosses the Abitibi at the Blacksmith's Rapids about thirty miles above the Moose. Lignite also exists on Coal river, a tributary of the Missanabie. Though not extensive these deposits are important as proving the existence of lignite in the region, and it is possible that future exploration may reveal large quantities of this mineral. An analysis of the coal from the Abitibi deposit, by W. A. Parks, Ph. D., gave:

Fixed carbon, 50.408 p. c.

Volatile matter, 38.63 p. c.

Moisture, 8.016 p. c.

Ash, 2.945 p. c.

Heating power, 6995 cal.

Perhaps this region is most important as a source of peat. It is claimed that the moss of the muskegs when decomposed forms peat of an excellent quality, and if this is the case the value of our wild, useless swamp lands is inestimable. The muskegs of value from this standpoint are very widely spread throughout the whole of Greater Ontario. Large areas occur in the Rainy River District and eastward to the great muskeg region in the basins of the Lower Moose and Albany rivers.

It seems probable that the water power now being wasted throughout the whole of Greater Ontario will be a very potent factor in commercial industries of all kinds when the country is opened up. Few countries are better supplied with natural power than this district. The number of rivers of large size with practically an unlimited water supply, and having usually very abrupt descents is sufficient in itself to guarantee that abundant power can be developed to supply all the needs of the country.

In conclusion is appended a list of what may be regarded as the more important resources of the country, and also a table showing the mean monthly temperatures at Moose Factory during 1878 and 1879.

Minerals.

Coal.—Deposits of Lignite on Coal and Abitibi rivers.

Gold.—Found on Sturgeon Lake, Lake Seul, Lake Minnetakie and other points in the Rainy River District. Along the north shore of Lake Superior and in parts of southern Algoma and Nipissing.

Silver.—Found at several points along the north shore of Lake Superior.

Iron.—North shore of Lake Superior and in parts of the Rainy River District and in southern Algoma and Nipissing.

Copper.—Same localities as iron.

Graphite.—Found in some districts north of Lake Superior.

Zinc.—North of Lake Superior.

Nickel.—Reported in districts north of Sudbury.

Anthraxolite.—Found in districts north of Sudbury.

Timber.

White Pine.—North of the Temagamingue country, and about the head waters of the Mattagami, also in the Rainy River District.

Red Pine.—Same as white pine.

Black Spruce.—Very common throughout the whole district.

White Spruce.—Found everywhere but less common than black spruce.

Banksian or Jack Pine.—Common everywhere on the more sandy soil.

Tamarac.—Common throughout the whole district especially in swampy parts.

Poplar.—Common on clay land and near water.

Balm of Gilead.—Same as poplar.

Birch.—Common throughout the whole district, found in same localities as poplar.

Balsam.—Common on clay land and near water.

Cedar—Occurs throughout district, generally in swamps or near water.

White Elm.—Found sparingly in Rainy River District and in the more southern parts.

Black Ash.—Occurs occasionally in the south and is of small size.

Fur and Game.

Black Bear.—Common in certain localities.

Polar Bear.—Occasionally seen about Moose Factory.

Moose.—Common in the more southern parts and in the Rainy River District, rare north of Lake Superior.

Woodland Cariboo.—Common in most parts except in the wetter muskegs.

Beaver.—Common in most parts.

Fox.—Common throughout the district.

Otter.—Common in most districts.

Marten.—Common in most districts.

Mink.—Common in most districts.

Fisher.—Common in most districts.

Weasel.—Common in most districts.

Musk-rat.—Common in most districts.

White Whale.—James Bay.

Lake Trout.—Common in larger lakes.

Sturgeon.—Found in some of the larger lakes and rivers.

Brook.—Common in many streams.

Pike.—Very common, found in nearly all lakes and rivers.

Pickerel.—Common.

Sucker.—Common everywhere.

White Fish.—Found in many lakes and streams.

Ducks.—Many varieties found everywhere in the district.

Geese.—Common in the district though only in the spring and fall.

Partridge, Grey and Spruce.—Common everywhere.

Prairie Chicken.—Common in parts of the Rainy River District, and said to be coming east along the burnt land about the C. P. R.

Table showing mean monthly temperatures at Moose Factory.

Months.	Temperatures Fahrenheit 1878, 1879.	
January	— 1.07°	— 3.92
February	13.71°	— 6.72
March	20.39°	12.08
April	35.59°	24.19
May	47.32°	39.95
June	57.04°	50.24
July	66.91°	60.26
August	62.99°	57.78
September	51.66°	48.98
October	40.94°	45.14
November	26.48°	20.80
December	7.57°	— 11.20

THE MADISON DRAW BRIDGE AT PORTLAND, OREGON.

By H. G. Tyrell, C.E., '86,

Designing Engineer for Boston Bridge Works.

The following bridge work is believed to be a typical case of first-class American Draw Bridge practice, and it is offered to the Engineering Society with the hope that it may be useful and interesting.

My calculations and strain sheets are given in full in the order that they were made.

In October, 1899, the City of Portland advertised for designs and bids for a highway and double track street railway bridge to cross the Willawette River at Madison Street, the bridge to replace the wooden one then in place.

The new bridge to consist of one steel swing span 316 feet long, and a width of 25 feet centre to centre of trusses, and a total width out to out of hand rail of 40 feet, and seven Pratt combination fixed spans of 190 feet in length each, and the same width as the swing span. The whole to be designed according to Thatcher's specification of 1894, with the following conditions:

Concentrated Live Load—2 electric cars coupled, on each track, weighing 20 tons each, or 15-ton road roller.

Uniform Live Load—100 pounds per square foot all over.

Roadway Floor—5-in. wood paving block on 3-in. plank, laid with ½-in. open joints, on 6 x 8 joist laid cross-wise of bridge 2½-ft. centres. All the above supported on steel stringers about 5-ft. apart.

Sidewalk Floor—2-in. plank on wood joist.

Roadway will be crowned 3 ins., and have cast scuppers in alternate panels on each side. Wood paving blocks 4 in. x 8 in. x 4 in. boiled in asphalt.

Material—Lateral rods, iron; drum and loading beams, soft steel; balance, medium steel.

Unit Stresses—Tension Only.

Chords, Ties, Counters, and Long Suspenders—

Wrought Iron.	Soft Steel.	Medium Steel.
$9400\left\{1+\frac{\text{Min.}}{\text{Max.}}\right\}$	$10800\left\{1+\frac{\text{Min.}}{\text{Max.}}\right\}$	$11700\left\{1+\frac{\text{Min.}}{\text{Max.}}\right\}$

Plates and Shapes—

$8500\left\{1+\frac{\text{Min.}}{\text{Max.}}\right\}$	$9700\left\{1+\frac{\text{Min.}}{\text{Max.}}\right\}$	$10500\left\{1+\frac{\text{Min.}}{\text{Max.}}\right\}$

Tension Flanges of Built Beams Girders, Same Gross Area as Compression Flanges.

Floor Beam Hangers through pin holes—

	Wrought Iron.	Soft Steel.	Medium Steel.
	6800	7800	8400
Lateral Rods	20000	23000	25000

Compression Only.

Flat Ends	$10750-399\frac{l}{r}$	$12500-500\frac{l}{r}$	$13750-577\frac{l}{r}$
One flat & one pin	$10750-444\frac{l}{r}$	$12500-556\frac{l}{r}$	$13750-642\frac{l}{r}$
Pin Ends	$10750-489\frac{l}{r}$	$12500-612\frac{l}{r}$	$13750-707\frac{l}{r}$

Lateral Struts, add 25% to above units for pin ends.

l=length of member in feet.

r=least radius of gyration in inches.

For top chords the stresses per square inch due to weight of member will be deducted from the above unit stresses.

The reduction for chords flat at one end being one-half, and for chors flat at both ends, one-third of the amount for members with pin ends.

No allowance will be made for wind stress combined with stress from dead and live load, unless the combined stress exceeds by 50 per cent. the stress from dead and live load only, in which case the combined stress will be used with a unit stress 50 per cent. greater than above given.

Girders.

In the compressed flanges of beams and girders, the allowed stress per square inch shall not exceed—

	Wrought Iron.	Soft Steel.	Medium Steel.
For riveted girders,	$\dfrac{9400}{1+.0288\frac{l^2}{b^2}}$	$\dfrac{10800}{1+.0288\frac{l^2}{b^2}}$	$\dfrac{11700}{1+.0288\frac{l^2}{b^2}}$
For rolled beams,	$\dfrac{10000}{1+.0288\frac{l^2}{b^2}}$	$\dfrac{11500}{1+.0288\frac{l^2}{b^2}}$	$\dfrac{12500}{1+.0288\frac{l^2}{b^2}}$

l = unsupported length in feet.

b = width of flange in inches.

Floor beams and stringers will be considered unsupported between end bearing.

Alternate Tension and Compression.

For the greater stress—

$$9400\left\{1 - \frac{\text{max. less}}{2 \times \text{max. greater}}\right\} \qquad 10800\left\{1 - \frac{\text{max. less}}{2\ \text{max. greater}}\right\}$$

$$11700\left\{1 - \frac{\text{max. less}}{2\ \text{max. greater}}\right\}$$

For compression only use compression formula.

Use the one giving the greatest area of section.

Combined Stress.

A member subject to transverse stress in addition to the tension or compression due to its position shall be considered as a beam of one panel length supported at the ends, for section in centre of panel, and fixed at ends, for sections at ends of panel. The member will be proportioned to sustain the algebraic sum of the stresses resulting from direct compression or tension and the transverse loading in which the allowed stress per square inch will not exceed—

	Wro't Iron	Soft Steel	Med. Steel.
At centre of panel	10000	11500	12500
At end of panel	12500	14400	15000
On pins and rivets shearing	9000	10000	11000
On webs of girder	6000	7000	7500
Diam. of pins and rivets bearing..................	15000	17000	19000
Extreme fibre of pins bending	20000	23000	25000

Field rivets will have 25 per cent. excess section over the above requirements.

Timber.

Fibre stress 1200 pounds per square inch.

Flat ends .... $1075 - 112\frac{l}{d}$

One flat and one pin .... $1075 - 125\frac{l}{d}$

Pin ends .... $1075 - 138\frac{l}{d}$

l = length of member in feet.
d = least diameter in inches.

Shearing—Sliding the grain	=	130	pounds	per square inch.
Direction of "	=	1200	"	"
Perpendicular "	=	300	"	"

Wind Bracing—Bottom lateral bracing will be proportioned to resist a uniformly distributed moving force of 300 lbs. per lineal foot.

Top lateral bracing to resist a uniformly distributed moving force of 150 pounds per lineal foot.

Track Stringer.

Steel, 21 feet long, about 5 feet apart.

M uniform live $= \dfrac{5 \times 21.1^2 \times 100}{8} = 25326$ foot pounds.

M from road roller $= 5456 \times 8 = 43648$ foot pounds.

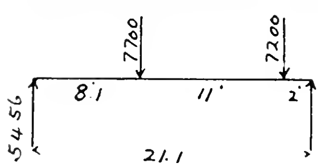


FIG I

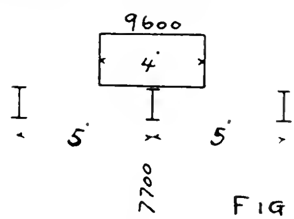


FIG 2

For dead moment, assume weights as follows:

4-in. paving @ 5 lbs.	=	20	lbs.	
3-in. plank @ $3\frac{1}{2}$ "	=	10.1	"	$\frac{1}{2}$-in. open joints.
Rails............................		4.	"	
Steel		9.		
6 x 8 cross joist $2\frac{1}{2}$ ft. c to c.		5.6	"	
		48.7	"	per sq. ft.

Then M dead $= \dfrac{48.7 \times 5 \times 21.1^2}{8} = 13551$ ft. lbs.

M live .... 43648 "

M total = 57199 "

Try riveted stringer—21 ft. long, unsupported sideways 4 angle's $5 \times 3 \times \frac{5}{16}$ 1 Pl.

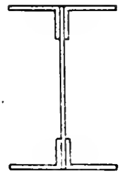


FIG 3.

Allowable stress per square inch =

$$= \frac{11700}{1 + .0288\frac{l^2}{d^2}} = 10430$$

$$\text{Required depth of web} = \frac{57199 \times 12}{10430 \times 4.8} = 13.71$$

Distance back to back = 13.71 + 2 (.68) = 15.07 inch.

Weight per lineal ft. = 45.55 lbs.

Try beam stringer, 21 ft. long, unsupported sideways, floor support not considered.

$$\text{Allowable stress per sq. in.} = \frac{12500}{1 + .0288\frac{l^2}{d^2}} = 8800 \text{ lbs.}$$

Required S $= \dfrac{57199 \times 12}{8800} = 78.$ S for 18 in. I @ 55 lbs. = 88.

Try beam stringer braced sideways, 10 ft. between supports. Allowable stress per square inch = 11400 lbs.

Required S $= \dfrac{57199 \times 12}{11400} = 60.2$ 15 in. I. @ 45 lbs. will do.

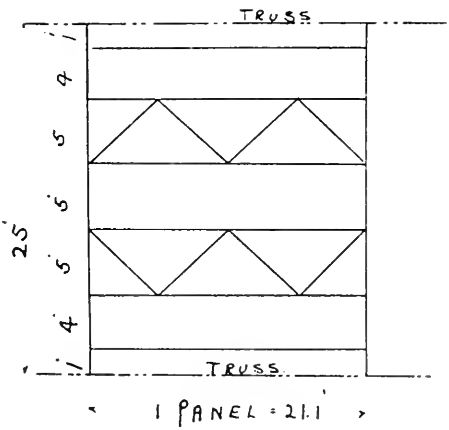


FIG 4.

Weight of stringer bracing for 2 beams:

4 angles $2\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{4} \times 7$	112 lbs.
5 pls. $8 \times \frac{1}{4} \times 1$ ft. – 3 ins.	40 "
5 angles $2\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{4} \times 1$ ft.-3 ins.	25 "
60 rivets	20 "
	197 "

For 1 beam = 98.5 lbs. = 4.7 lbs. per ft.

Beam......................	45.0	"	"
Total...........	49.7	"	"

Comparative economy of 3 stringers:

Built stringer, 45.55 lbs. @ .0267c. per lb.	= 1.2282c.	
18 in. I @ 55 lbs. @ .0247c. per lb.	= 1.3585c.	
15 in. I @ 45 lbs. @ .0237c. "	= 1.0665c.	Use this.
Bracing 4.7 lbs. @ .0275c. "	= .1292c.	
	1.1957c	

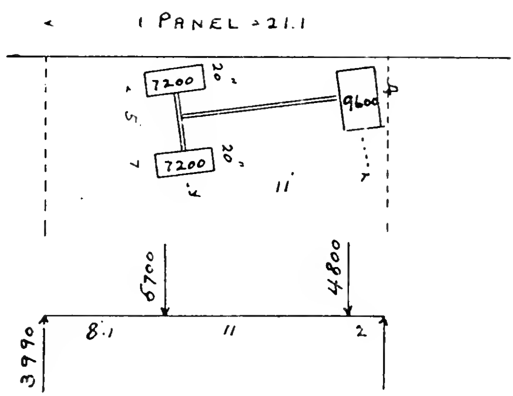


FIG 5.

Side stringer. M uniform live $= \dfrac{3 \times 21.1^2 \times 100}{8} = 16530$ ft. lbs.

M from road roller $= 3990 \times 8 = 31920$ ft. lbs.

Dead load per lin. ft. on side stringer. (See section.)

Paving,	$20 \times 2\frac{1}{4}$	= 80.3 lbs.
3-in. plank,	$10.1 \times 2\frac{1}{4}$	
6 x 8 joist,	$5.6 \times 2\frac{1}{4}$	
Steel....................		40. "
Guard		10.5 "
Walk plank		7. "
		137.8 "

Then M dead $= \dfrac{137.8 \times 21.1^2}{8} = 7668$ ft. lbs.

M live........................... = 31920 "

M total .... = 39588 "

Required S.

Unsupported 21 ft. $\dfrac{39588 \times 12}{8800} = 54.$

15 in. I @ 42 lbs. has S = 58.9 which use.

Walk stringer 2 ft. apart.

Load, live.............	= 100 lbs.	per sq.	ft.
dead	15	"	"
Total	115	"	"

Total load on stringer = 115 × 2 × 21 = 4830 lbs., use 4 x 14.

For outside stringer with half load, use 3 x 14.

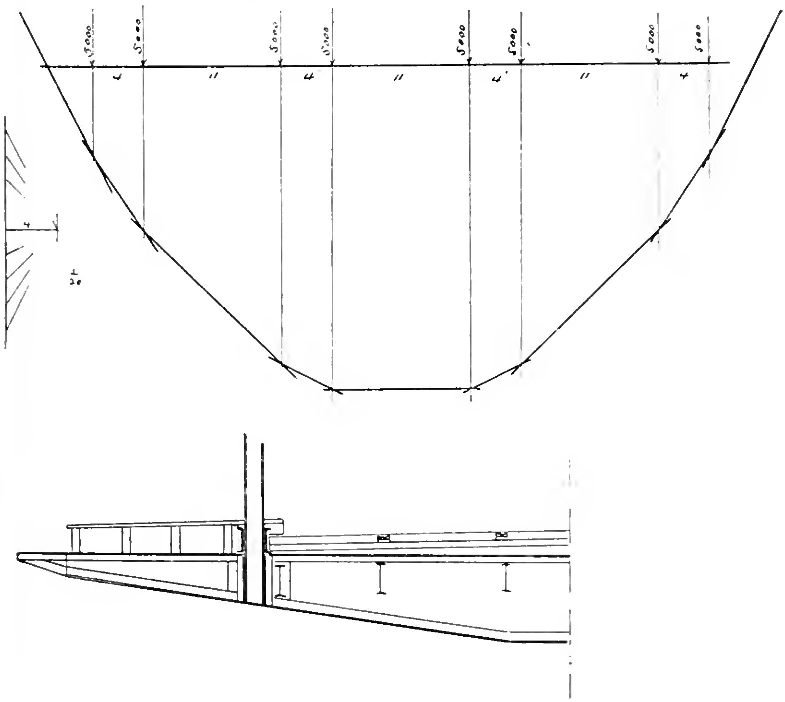


FIG 6.

Floor Beam.

Dead load at $I' = 4\frac{1}{2} \times 48.7 \times 21.1 = 4621$ lbs.
" $I = 5 \times 48.7 \times 21.1 = 5137$ "

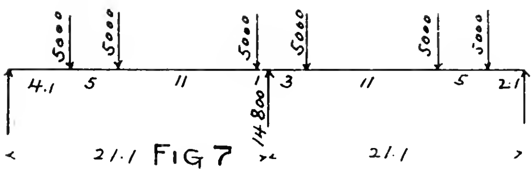


FIG 7

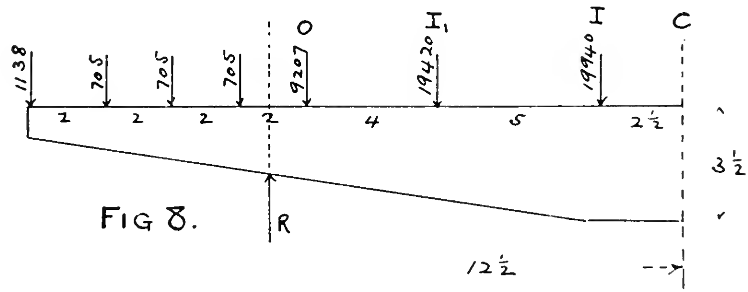


FIG 8.

	ft. lbs.
M at $O = 1138 \times 8 + 705 \times 12 - 51820 \times 1$	$= 34260$
" $I_1 = 1138 \times 12 + 705 \times 24 + 9207 \times 4 - 51820 \times 5$	$= 191700$
" $I = 1138 \times 17 + 705 \times 39 \times 9207 \times 9 + 19420 \times 5 - -51820 \times 10$	$= 291413$

Max. shear—R O $= 48570$
O I_1 $= 39360$
I_1 I $= 19940$ for 2 tracks.
I_1 C $= 9000$ for 1 track.

Required flange area at I $= \dfrac{291413 \times 12}{40.1 \times 10450} = 8.34$ sq. in. Use 2

Angles $6 \times 4 \times \frac{7}{16} = 8.36$ sq. in. gross.

Required depth at $I_1 = \dfrac{191700 \times 12}{10450 \times 8.36} = 26.2$ inches effective.

$26.2 + 1.90 = 28.1$ back to back.

Bottom flange area will be same as top.

Walk Bracket.

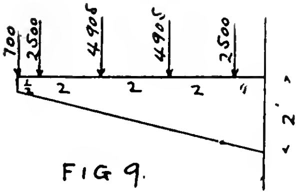


FIG 9.

$M = 2500 \times 1 + 4905 \times 8 + 2500 \times 7 + 700 \times 7\frac{1}{2} = 64490$ ft. lbs.

$$\text{Flange stress} = \frac{64490}{1.8} = 35800 \text{ lbs.}$$

$$\text{Flange area required} = \frac{35800}{11400} = 3.14$$

square inches.

Use 4 angles $3\frac{1}{2} \times 2\frac{1}{2} \times \frac{5}{16}$, $\frac{1}{4}$-in. web plate.

Top Laterals.

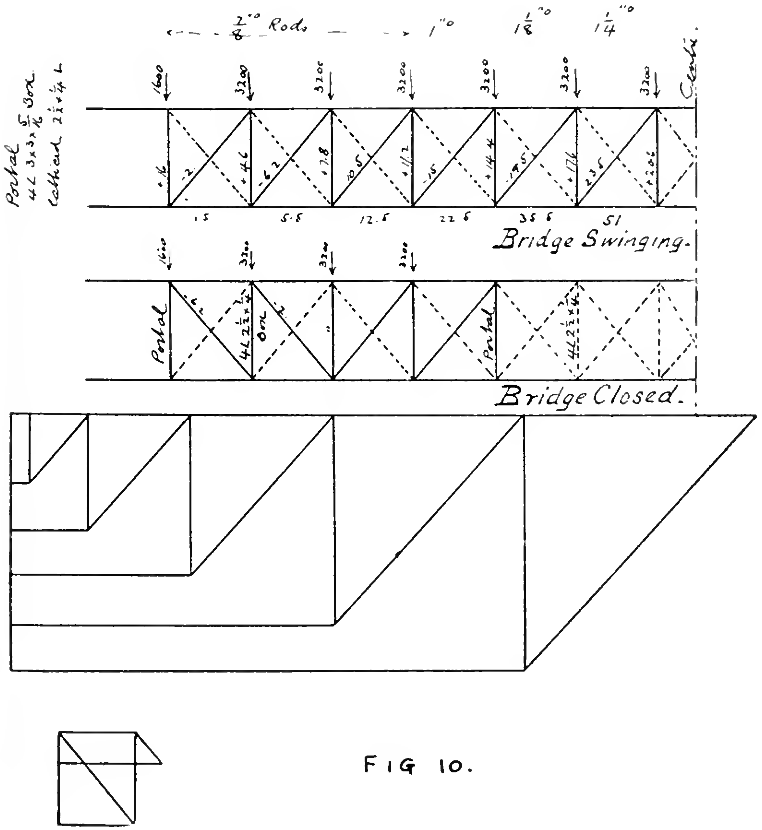


FIG 10.

Bottom Laterals.

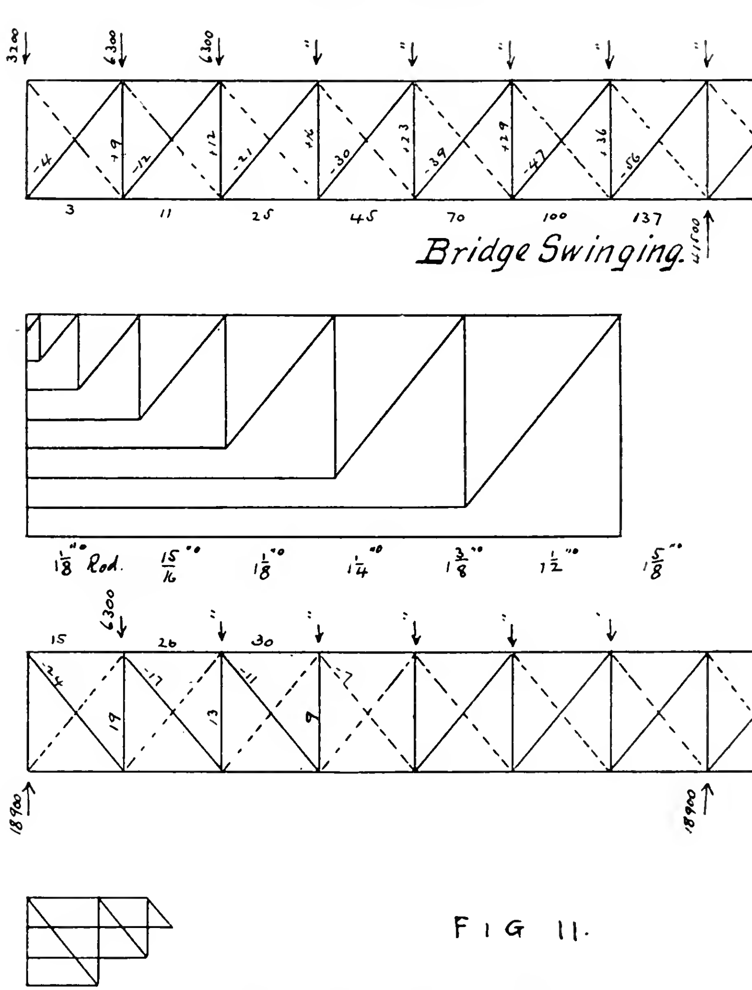


FIG 11.

Weight of Laterals (Half Span).

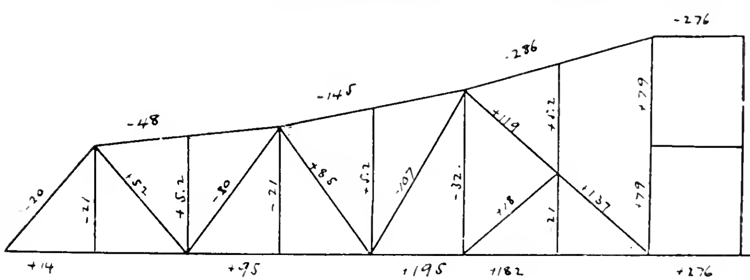
Upper—

6 rods	⅞-in. x 35 ft. long	- - - - -	420
2 "	1-in. x 35 "	- - - - -	189
2 "	1⅛-in. x 35 "	- - - - -	238
3 "	1¼-in. x 35 "	- - - - -	440
			——1287

Lower—		
4 rods $1\frac{1}{8}$-in. x 35 ft. long	476	
2 " $\frac{15}{16}$-in. x 35 "	161	
2 " $1\frac{1}{4}$-in. x 35 "	294	
2 " $1\frac{3}{8}$-in. x 35 "	350	
2 " $1\frac{1}{2}$-in. x 35 "	420	
3 " $1\frac{5}{8}$-in. x 35 "	735	
		2436
Sways—		
8 rods 1-in. x 26 ft. long; 4 " 30 "; 4 " 32 "; 4 " 37 "	1628	
8 " $1\frac{1}{4}$-in. x 35 "	1176	
		2804
2 Portals—		
8 angles 3 x 3 x $\frac{5}{16}$ x 27 ft.	1317	
24 angles $2\frac{1}{2}$ x $2\frac{1}{2}$ x $\frac{1}{4}$ x 6 ft.; 24 " " 3 ft.	885	
Details	600	
		2802
4 Top Struts—		
16 angles $2\frac{1}{2}$ x $2\frac{1}{2}$ x $\frac{1}{4}$ x 25 ft.	1640	
Details	680	
		2320
4 Portal Brackets—		
8 angles 3 x 3 x $\frac{1}{4}$ x 8 ft	320	
8 angles $2\frac{1}{2}$ x $2\frac{1}{2}$ x $\frac{1}{4}$ x 3 ft.; 4 " " 4 ft.	160	
Details	320	
		800
6 Sway Struts—		
24 angles $2\frac{1}{2}$ x $2\frac{1}{2}$ x $\frac{1}{4}$ x 24 ft.	2361	
Details	1020	
		3381

Dead weight per lineal foot of bridge—

Paving $23\frac{1}{2}$ ft. wide 4 in. thick @ 5 lbs. =	470
3-in. plank $23\frac{1}{2}$ ft. wide @ $3\frac{1}{2}$ lbs. =	236
6 x 8 wood joist @ $3\frac{1}{2}$ lbs. =	131
Rails, 80 less 28 paving	52
Walk plank, 17 ft. x 2 in. thick, $\frac{1}{2}$-in. open joints,	114
2 guards, 6 x 6	21
6 joist, 4 x 14 on walk	98
2 " 3 x 14 "	24.5
Hand rail	60
Steel stringers	264
Floor beams	140.8
Lateral system	100.2
Stringer bracing	18.7
Trusses (assumed)	750.
Total dead weight per lineal ft. =	2479.



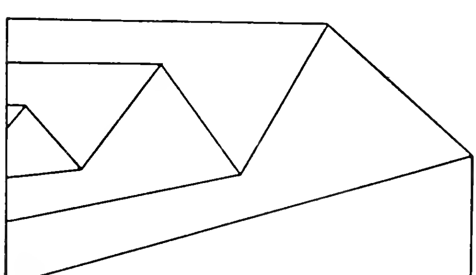


FIG 12

Trusses.

Assume the following cases for loading :

(1) Dead load, ends simply touching supports (2) Live load symmetrical, continuous girder, 4 supports	Combine.
(3) Dead load, simple span (4) Live " " "	Combine.

Case 1.—Dead load, per foot of bridge = 2,479 lbs.

" " " panel, per truss = 26,200 lbs.

Case 2.—Live load symmetrical, continuous girder, four supports.

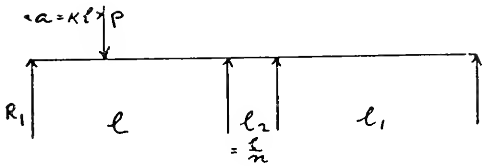


FIG 13.

$$R1 = \frac{P}{H}\left\{H - (H + 2n + 2n^2)K + (2n + 2n^2)K^3\right\} \text{ where } H = 3 + 8n + 4n^2$$

Live load per lineal foot of bridge = 3,300 lbs.

" " " panel per truss = 34,800 lbs.

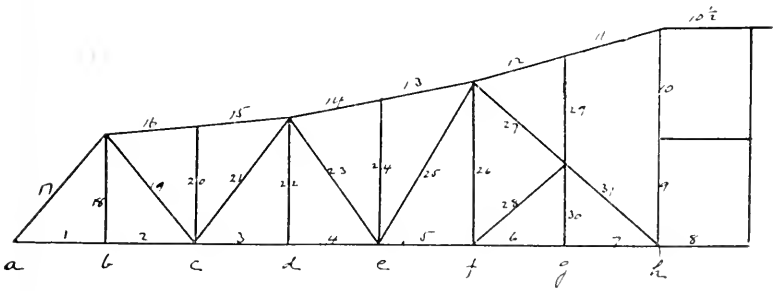


FIG 14

Max. Reaction R1 :

Loads at b c d e f g	2.293	×	34800	=	79800
c d e f g	1.494	×	"	=	52000
d e f g	.888	×	"	=	30900
e f g	.461	×	"	=	16000
f g	.191	×	"	=	6650
g	.049	×	"	=	1700

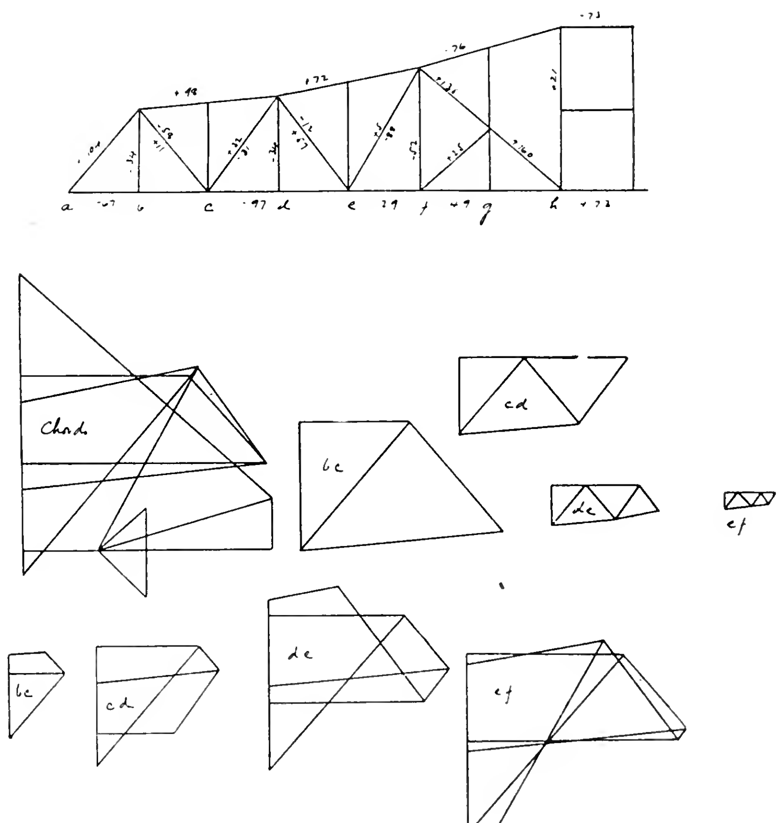


FIG 15.

Max. Reaction R1 :

Loads at b	.799 ×	34800	=	27800
b c	1.405 ×	"	=	48900
b c d	1.832 ×	"	=	63700
b c d e	2.112 ×	"	=	73500
b c d e f	2.244 ×	"	=	78100
b c d e f g	2.293 ×	"	=	79890

Case 3.—Each arm single span. Dead load.

Dead load per foot of bridge = 2479 lbs.

" " panel per truss = 26200 lbs.

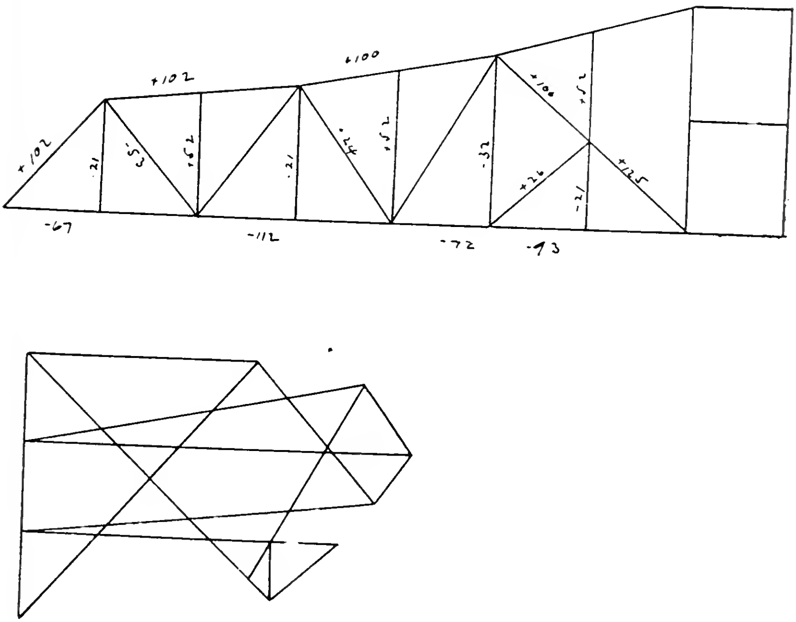


FIG 16.

Case 4.—Each arm single span. Live load.

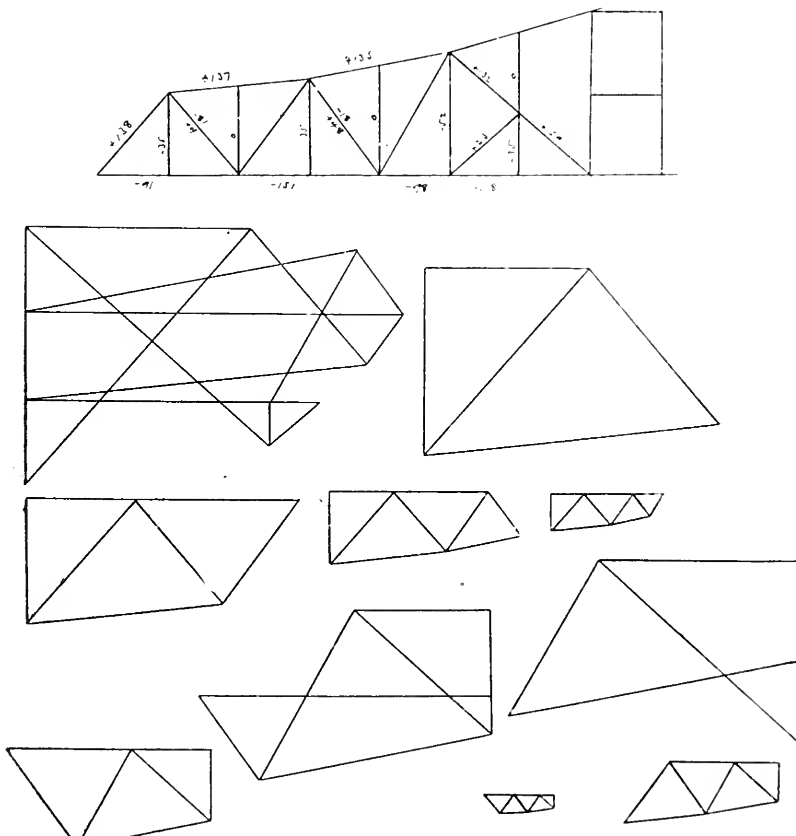


FIG 17

TABLE OF STRESSES.

Member	Case 1. (Combine these.)		Case 2. (Combine these.)		Case 3. (Combine these.)		Case 4. (Combine these.)		Combined. Max. Stresses +	Combined. Max. Stresses —
1	+ 14			— 67		— 67		— 91	14	158
2	+ 14			— 67		— 67		— 91	14	158
3	+ 95			— 97		—112		—151	95	263
4	+ 95			— 97		—112		—151	95	263
5	+195			— 29		— 72		— 98	195	170
6	+182			— 49		— 93		—118	182	211
7	+182			— 49		— 93		—118	182	211
8	+276		+ 73			o		o	349	
9	+ 79		+ 21			o		o	100	
10	+ 79		+ 21			o		o	100	
10½		—276		— 73		o		o		349
11		—286		— 76		o		o		362
12		—286		— 76		o		o		362
13		—145	+ 72		+100		+135		235	145
14		—145	+ 72		+100		+135		235	145
15		— 48	+ 98		+102		+137		239	48
16		— 48	+ 98		+102		+137		239	48
17		— 20	+104		+102		+138		240	20
18		— 21		— 34		— 21		— 34	o	55
19	+ 52			— 58		— 53	+ 9	— 81	63	134
20	+ 5 2		o		+ 5·2			o	5	
21		— 80	+ 32	— 32	+ 17		+ 51	— 27	68	111
22		— 21		— 34		— 21		— 34		55
23	+ 85		+ 57	— 12	+ 24		+ 48	— 18	142	18
24			o	o	+ 5·2			o	5	
25		—107	+ 5	— 88		— 52	+ 8	— 78	8	195
26		— 32		— 52		— 42		— 52		84
27	+119		+135		+100		+132		254	
28	+ 25		+ 25		+ 21		+ 25		50	
29	+ 5.2		o		+ 5.2			o	5	
30		— 21		— 34		— 21		— 34		55
31	+137		+160		+125		+159		297	

Proportioning Members.

No. 1 and 2 + 14000, − 158,000.

For alternate tension and compression unit =

$$11700\left\{1 - \frac{\text{max. less}}{2\ \text{max. greater}}\right\} = 11200 \text{ lbs.}$$

From dead weight of member. Stress per sq. in. on outer fibre. $\Big\} = \dfrac{21 \times 50 \times 21 \times 12}{8 \times 42 \times 3} = 260.$

Allowable unit = 11200 − 260 = 10940 lbs.

Required sectional area = $\frac{158000}{10940}$ = 14.4 sq. in.

Use 2 channels 12 in. @ 25 lbs. = 14.7 sq. in. gross.

No. 3 and 4. Stresses are + 95000 and − 263000.

For alternate tension and compression unit = 9734
Less for dead weight 270

9464 lbs. per sq. in.

Required sectional area = $\frac{263000}{9464}$ = 27.7 sq. in.

Use 2 channels 12 in. @ 30 lbs. = 18 sq. in. gross.
2 Pls. $11\frac{3}{4} \times \frac{3}{8}$ - - - - - - = 9 " "

Total - - 27 " "

No. 5. Stresses are + 195000 and − 170000.

For all compression unit is $13750 - 707\frac{l}{r}$, where $\frac{l}{r} = \frac{21}{4.2} = 5$.

Hence " " " 10215 lbs.

From dead weight of member, stress per sq. in. on outer fibre = $\frac{21 \times 90 \times 21 \times 12}{8 \times 52 \times 3}$ = 470 "

Allowable for direct compression - - 9745 " per sq. in.

For alternate tension and compression unit =

$$11700 \left\{ 1 - \frac{16600}{2 \times 180000} \right\} = 6282$$

From dead weight unit = 380

Total allowable unit - 5902

Required sectional area = $\frac{195000}{5902}$ 33.1 sq. in. gross.

Use 2 channels 12 in. @ 35	21 sq. in. gross.	
2 plates $11\frac{3}{4} \times \frac{1}{2}$	12 "	"
	33 "	"

No. 6 and 7. Stresses are + 182000 and − 211000

For all compression unit = 10200

Less from dead weight 400

9800

For alternate tension and compression unit =

$$11700\left\{1 - \frac{165000}{2 \times 204000}\right\} = 6973 \text{ lbs.}$$

Less from dead weight 400 "

6573 "

Required sectional area $= \frac{211000}{6573} = 32.1$ sq. in.

Use 2 channels 12 @ 35 = 21 sq. in. gross.

2 plates 12 × ½ 12.5 " "

33.5 " "

Dead, live and wind for No. 6 + 282000 and − 281000

" " " " " " 7 + 319000 and − 311000

Unit for above = 6573 + (50% of 6573) = 9858

282000 ÷ 9858 = 28.6 sq. inches } both of which are less than

319000 ÷ 9858 = 32.4 " " } for dead and live only.

No. 8. Stress is 349000 lbs.

For all compression, 2 square ends, unit =

10800 lbs. per sq. in.

Less from dead weight 400 " " " "

10400 " " " "

Required sectional area $= \frac{349000}{10400} = 33.5$ sq. in.

Use 2 channels 12 in. @ 35 lbs. = 21 sq. in.

2 plates 12 × ½ 12 " "

Total - - 33 " "

No. 9. Stress is + 100000 lbs.

$\frac{l}{r} = \frac{24}{3.5} = 7.1$ Unit $= 13750 - 642 \frac{l}{r} = 9130$ lbs.

Required sectional area $= \frac{100000}{9130} = 10.6$ sq. in.

Use 2 channels 10 @ 20 lbs. = 12 sq. in.

No. 10 is same as No. 9.

No. $10\frac{1}{2}$ Stresses – 349000 and – 260000.

Unit stress for all tension = $11,700 \left\{ 1 + \frac{\text{min.}}{\text{max.}} \right\}$

$$11700 \left\{ 1 + \frac{260,000}{349,000} \right\} = 20830 \text{ lbs.}$$

Required sectional area – $\frac{349000}{20830}$ 16.6 sq. in.

Use 4 bars $4\frac{3}{4} \times \frac{7}{8}$ in. 16.6 sq. in

No. 11 and 12. Stresses are – 362000 and – 271000.

$$11700 \left\{ 1 + \frac{\text{min.}}{\text{max.}} \right\} \quad 20840$$

Required area – $\frac{362000}{20840}$ 17.3 sq. in.

Use 4 bars $5 \times \frac{7}{8}$ 17.5 sq. in.

No. 13 and 14. Stresses are + 235000 and – 145000.

For all compression unit 10800 lbs.
Less from dead-weight 400 "

10400

For alternate tension and compression unit =

$$11700 \left\{ 1 - \frac{\text{max. less}}{2\text{max. greater}} \right\} \quad 8280 \text{ lbs.}$$

Less from dead weight 380 lbs.
7900 "

Required sectional area $\frac{235000}{7900}$ 29.6 sq. in.

Use 2 channels 12 @ 35 lbs. 21 sq. in.
1 Plate $18 \times \frac{1}{2}$ 9 "

Total 30 "

No. 15 and 16. Stresses are 239000 and – 48300 lbs.
For all compression unit 10400

For alternate tension and compression	=	10620
Less from dead weight		400
		10220

Required sectional area $= \frac{233000}{10200} = 22.8$ sq. in.

Use 2 channels 12 @ 30	=	18	sq. in.
1 Plate $18 \times \frac{5}{16}$		5.6	"
Total	=	23.6	"

No. 17. Stresses are + 240000 and − 20000.
For all compression unit = 8660.

Required area $= \frac{232000}{8660} = 26.8$ sq. in.

Use 2 channels 12 @ 35	=	21.
1 Pl. $18 \times \frac{3}{8}$	=	6.7
Total - -		27.7 sq. in.

No. 18, 22, 30. Stresses − 55000 and − 19000.

Unit for all tension $= 10500 \left\{1 + \frac{\text{min.}}{\text{max.}}\right\} = 14300$ lbs

Required sectional area $= \frac{53000}{14300} = 3.7$ sq. in.

Use 2 channels 8 @ $11\frac{1}{4}$ = 6.6 sq. in. gross.
4.5 " net.

No. 26. Stresses are − 84000, and − 32000.
Unit for all tension, 14500 lbs.

Required sectional area $= \frac{84000}{14500} = 5.8$ sq. inches.

Use 2 channels 9 in. @ $13\frac{1}{4}$ lbs. = 8 sq. in.

No. 20 and 24. Stress + 5200. Use 2 [8 @ $11\frac{1}{4}$ lbs.

No. 19. Stresses are + 63000 and − 134000.
Allowable unit = 9160 lbs.

Required sectional area $= \frac{131000}{9160} = 14.3$ sq. in.

Use 2 channels 9 @ 25 lbs. = 14.7 sq. in.

No. 21. Stresses are + 68000 and − 111300.

Allowable unit 7830.

Required sectional area $\frac{111300}{7830} = 13.1$ sq. in.

Use 2 channels 9 @ 25 lbs. = 14.7 sq. in. gross.

No. 23. Stresses are + 142000 and − 18000.

Unit for all compression = 7950 lbs. per sq. in.

" " alternate tension and compression 10900

Required sectional area $\frac{142000}{7950} = 17.7$ sq. in.

Use 2 channels 12 @ 30 lbs. 18 sq. in.

No. 25. Stresses are + 8000 and − 195000.

Unit for all tension $= 11700\left\{1 + \frac{\text{min.}}{\text{max.}}\right\} = 14620$ lbs.

Required sectional area $= \frac{195000}{14620} = 13.3$ sq. in.

Use 4 bars $4\frac{1}{2} \times \frac{3}{4}$ 13.5 sq. in.

No. 27. Stress = + 254000.

$\frac{l}{r} = \frac{28}{5.6} = 5$ allowable unit = 10540 lbs.

Required sectional area $\frac{254000}{10540}$ 23 sq. in.

Use 2 channels 15 @ 33 lbs.	19.8 sq. in.
1 Plate $18 \times \frac{1}{4}$	4.5
	24.3 " "

No. 31 Stress + 297000.

Required sectional area $\frac{297000}{10540} = 28.1$ sq. in

Use 2 channels 15 @ 33 lbs.	19.8 sq. in
1 Plate $18 \times \frac{7}{16}$	7.9 " "
	27.7 " "

No. 28. Stress = + 44000.

$\frac{l}{r} = \frac{28}{3.1} = 9$ allowable unit = 7387 lbs.

Required sectional area $\frac{44000}{7387} = 6$ sq. in.

Use 2 channels 8 @ $11\frac{1}{4}$ lbs. = 6.6 sq. in.

Weight and Quantities in bridge above turntable.

2 Trusses	@ 120140	240280
12 Floor Beams Intermediate	2602	31224
2 " " End	2100	4200
15 Panels Stringer Bracing	394	5910
2 Lines Stringer 15 in. I @ 42		} 83952
4 " 15 in. I @ 45		
32 Walk Brackets	368	11776
Operator's Platform		4384
Top Laterals		2788
Bottom Laterals		6635
4 Portals		5560
18 Top Struts		10440
12 Portal Brackets		2400
2 Tower Portals		2780
Sway Rods		3200
Ladder		500
28 Railing Posts	48	1400
4 Trolley Poles	514	2056
2 Trolley Struts	738	1476
900 Hook Bolts		700
120 Plain Bolts		360
		422021

90 ft. Gas Pipe Railing
630 ft. Lattice Railing
4 Cast Iron Newel Posts
Wood Joist 11.1 M.
Flooring, etc., 44.9 M.
Wood Block Paving 4 in. deep = 825 sq. yds. 29700 ft. B.M.

Maximum Stress in Thousands.

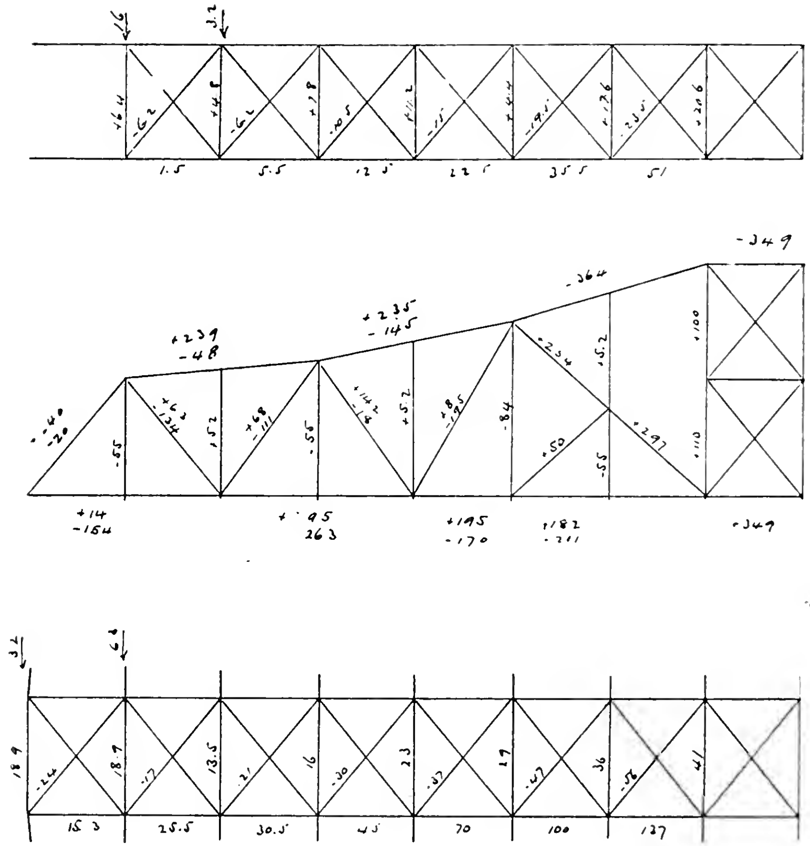


FIG 18.

Diagram of Sizes.

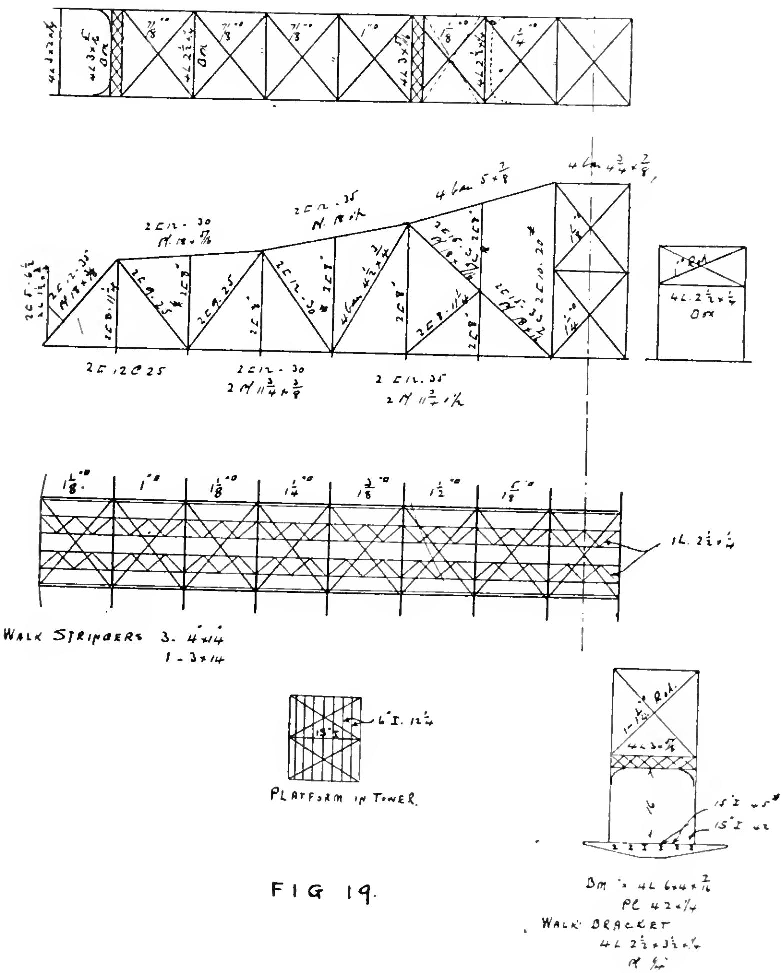


FIG 19.

Trolley Support at End of Draw.

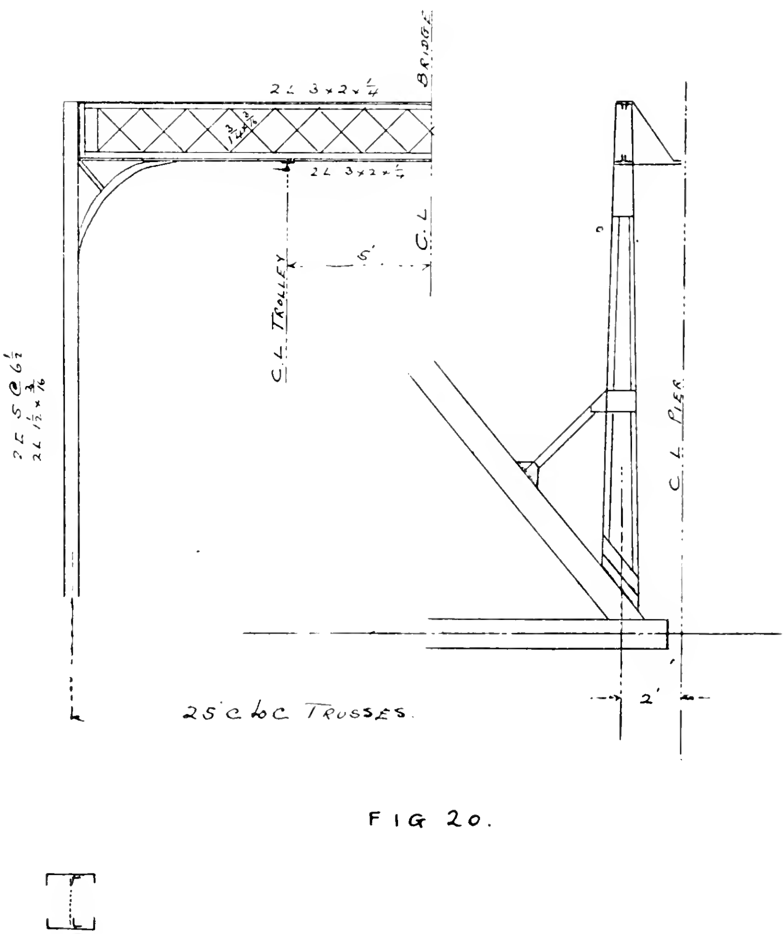
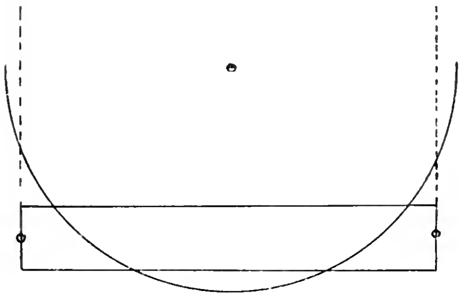


FIG 20.

Drum (Soft Steel) 27 ft. Diam.



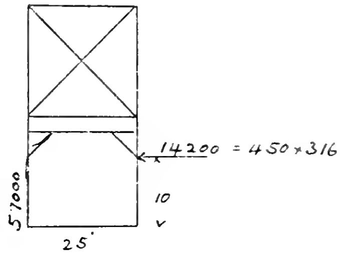


FIG 21 FIG 22.

Max. Load on Drum.		Lbs.
With draw closed.—Live load	3300 × 168 =	554400
Dead load	2480 × 316 =	783700
Centre platform		25000
Total load on drum	=	1363100
Load on half drum		681600
Wind		57000
		738600
$\frac{1}{4}$ load on drum		369300
Load on Drum.		
Draw open.—Dead, 2480 × 316		783700
Snow, 800 × 316		252800
Centre platform		25000
		1061500
Load on $\frac{1}{4}$ drum		265400
Wind		28500
Max. load on $\frac{1}{4}$ drum		293900

The above considers 1 foot of snow all over bridge and walk, only when draw is open.

Loading beam distributes $\frac{1}{4}$ load of bridge on two points about 6 ft. apart.

Consider 3 wheels not bearing. Then Drum is a girder 6 ft. long, with centre Load 135000 lbs.

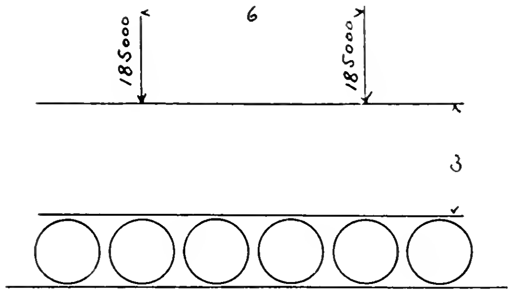


FIG 23.

Hence Required Flange Area is $\frac{92500 \times 3}{3 \times 9000} = 10.3$ sq. in. net.

Use 2 angles $5 \times 5 \times \frac{1}{2} = 8$ sq. in. net.

1 Cover Plate $16 \times \frac{1}{2}$ 7

Total 15

Max. Shear 185000 lbs.

Web Area Required $= \frac{185000}{9000} = 19$ sq. in.

Use Plate $36 \times \frac{1}{2} = 18$ sq. in.

With stiffeners $4 \times 3 \times \frac{1}{2}$ angles.

Wheels, say 20 in. diameter.

Circumference of Track is about 81 ft. Hence use say 40 wheels. Allowable pressure on wheels per lineal inch $= 600\sqrt{d}$ live
$1200\sqrt{d}$ dead

Total Live Load 554400 lbs.

" Dead " 808700 lbs.

" Lineal inches required $554400 \div 2680 = 207$ inches.
$808700 \div 5360 = 151$ "

Total 358 "

Hence Face of Wheel $= 358 \div 40 =$ say 9 in.

Loading Beam (Soft Steel).

Max. load on 1 quadrant of drum = 369300

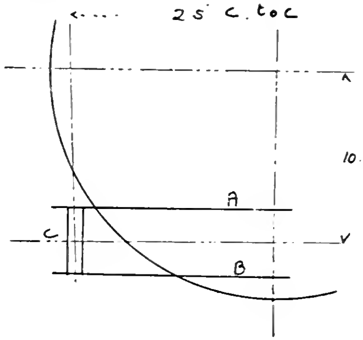


FIG 24.

Inside beam A.—

Required flange area $= \dfrac{369300}{2} \times \dfrac{2}{2.5 \times 12000} = 12.3$ sq. in.

Use 2 angles $6 \times 6 \times \frac{5}{8} = 12$ sq. in. net.
Web, $30 \times \frac{1}{2}$, reinforced with 2 plates $\frac{3}{8}$ in. thick at ends.

Outside beam B.—

$M = \dfrac{369300}{2} \times 6$. Assuming beam 30 in. deep, then flange area $= \dfrac{369300 \times 6}{2 \times 2.5 \times 12000} = 37$ sq. in.

$\frac{1}{6}$ of 2 web plates, $30 \times \frac{5}{8}$ =	6 sq. in.
2 plates, $20 \times \frac{1}{2}$	16 "
2 angles $6 \times 6 \times \frac{7}{8}$	16 "
	38 "

Max. shear = 185000.
Web area = $185000 \div 7000 = 26$ sq. in. Use 2 webs, $30 \times \frac{5}{8}$ = 26 sq. in. net.

Girder C.—Flange area required $= \dfrac{369300 \times 2}{2 \times 2. \times 12000} = 15.5$ sq. in.

Use 2 angles $6 \times 6 \times \frac{3}{4} = 15$ sq. in net.
Shear = 185000. Use 2 pls. $28 \times \frac{5}{8}$.

Turning Gear.

What is the required horse-power to turn bridge?

No wind acting.

From experiments by Mr. A. P. Boller on the new London drawbridge, he deduced the following rule:

$$\text{H.P.} = \frac{.01wv}{550}, \quad \text{where } w = \text{weight of bridge pounds.} \quad \text{" } v = \text{velocity in feet per second at rack.}$$

$$= \frac{.01 \times 973000 \times .67}{550} = 11.8$$

Velocity assumed for end of draw = 6 miles per hour (average).

This turns bridge through 90 deg. in 30 seconds.

Extra power required to open bridge against an unbalanced wind pressure of 5 pounds per sq. ft. on total exposed surface of bridge.

Wind pressure on half bridge (one end) = $15 \times 158 \times 5$.

$$\therefore \text{Thrust at rack} = \frac{15 \times 158 \times 5 \times 158}{13.5 \times 2} = 62400 \text{ lbs.}$$

Length of quadrant = 23.5 ft. $\therefore$ Work done = 62400 lbs. $\times 23\frac{1}{2}$ = ft., lbs. in 30 seconds.

$$\therefore \text{H.P.} = \frac{62400 \times 23\frac{1}{2}}{2 \times 33000} = 22.$$

Total required H.P. = wind	22.
Friction and inertia	11.8
	33.8

Use say 30 H.P. General Electric motor, which will stand overloading to about twice its rated capacity.

Rack. Proportion this for capacity of 30 H.P. motor. Work done on rack $23\frac{1}{2}$ ft. long in 30 sec. = $30 \times 33000 \times 2$.

$$\therefore \text{Thrust on rack} = \frac{30 \times 33000 \times 2}{23.5} = 84000 \text{ lbs.}$$

Assume this thrust of 84000 lbs. resisted by 2 teeth.

42000 " " " 1 tooth.

For cast iron 1200 p. f. = 42000, p. and f. are pitch and face of rack.

Assume face = 9 in. Then pitch = 3.7 in.—circular.

Turning Gear.

Hand lever.

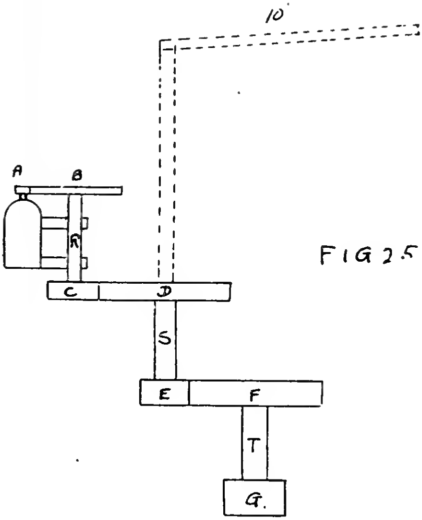


FIG 25

Gears A and B go with motor. A has 14 teeth, and $4\frac{2}{3}$ in. diameter. B has 67 teeth, and $22\frac{1}{3}$ in. diameter. Shaft R is $3\frac{1}{4}$ diameter to fit motor boxes.

Take average speed of motor at 400 revolutions per minute. Then shaft R has 85 revolutions per minute.

If bridge opens in 30 seconds, then speed of shaft T is $11\frac{1}{2}$ revolutions per minute. Therefore required speed reduction is $\frac{85}{11.5} = 7.4$.

Use 2 reductions of 3.7 each.

Then if we assume pinions E and C at 9 in. diameter each, gears D and F will be $9 \times 3.7 = 33.3$ in. diameter.

To proportion teeth, use the following formula: $W = 1200$ p. f. where W = thrust on tooth, p. and f. are pitch and face.

Gears are steel. C and D have $1\frac{1}{2}$ in. pitch, $4\frac{1}{2}$ in. face.
E " F " $2\frac{1}{2}$ " 6 "
G has $3\frac{3}{4}$ in. pitch, 9 in. face, 15 in. diameter.

To proportion shafts, use the following formula for steel:

Diameter $= \sqrt[3]{\frac{T}{2200}}$, where T = tortional moment in inch lbs.

Hence shaft S = $4\frac{3}{4}$ in. diam. Shaft T = 6 in. diam.

Hand Turning Arrangement.

Number of revolutions of pinion required to open draw = $5\frac{1}{2}$ in 30 seconds. Number of revolutions of lever required to open draw = $5\frac{1}{2} \times 3.7 = 20$.

Circumference of walk $= 10 \times 2 \times \pi =$ say 60 feet.

$\therefore$ Distance walked in opening draw $= 60 \times 20 = 1200$ ft.

If man walks $2\frac{1}{2}$ miles per hour, or 240 ft. per minute, then time required to open bridge by hand is $1200 \div 240 = 5$.

Power required with no wind blowing is 11.8 H. P. to open bridge in 30 seconds.

Hence power required to open bridge is 5 minutes $= \frac{11.8}{5 \times 2} =$ 1.18 H. P. $= 1.18 \times 33000 = 38900$ ft. lbs. per minute.

One man can push 50 lbs. on lever while walking. Hence 1 man power $= 240 \times 50 = 12000$ ft. lbs. per minute. Hence number of men required $= \frac{38900}{12000} =$ say 3 men.

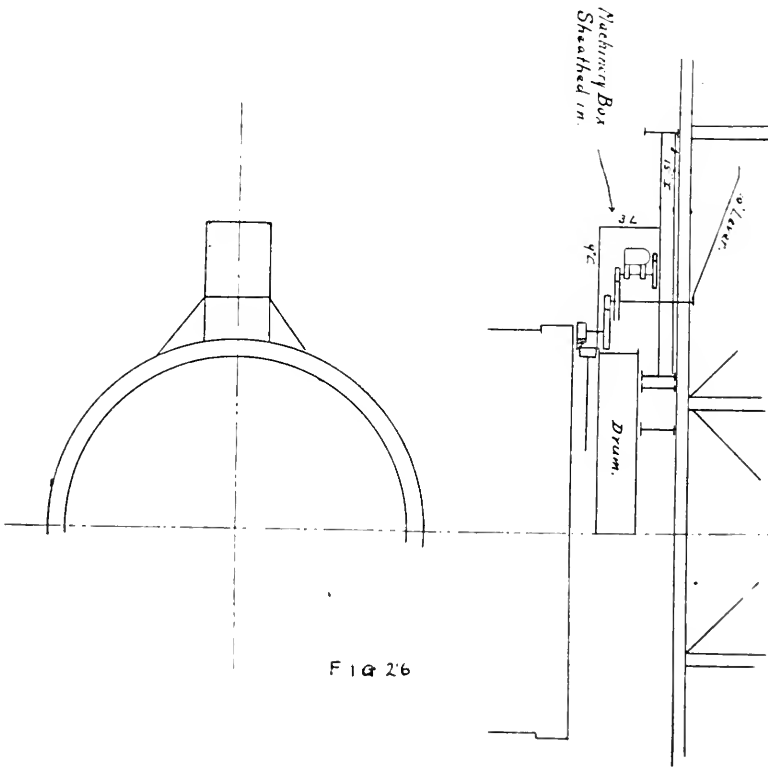


FIG 26

Turn-table.

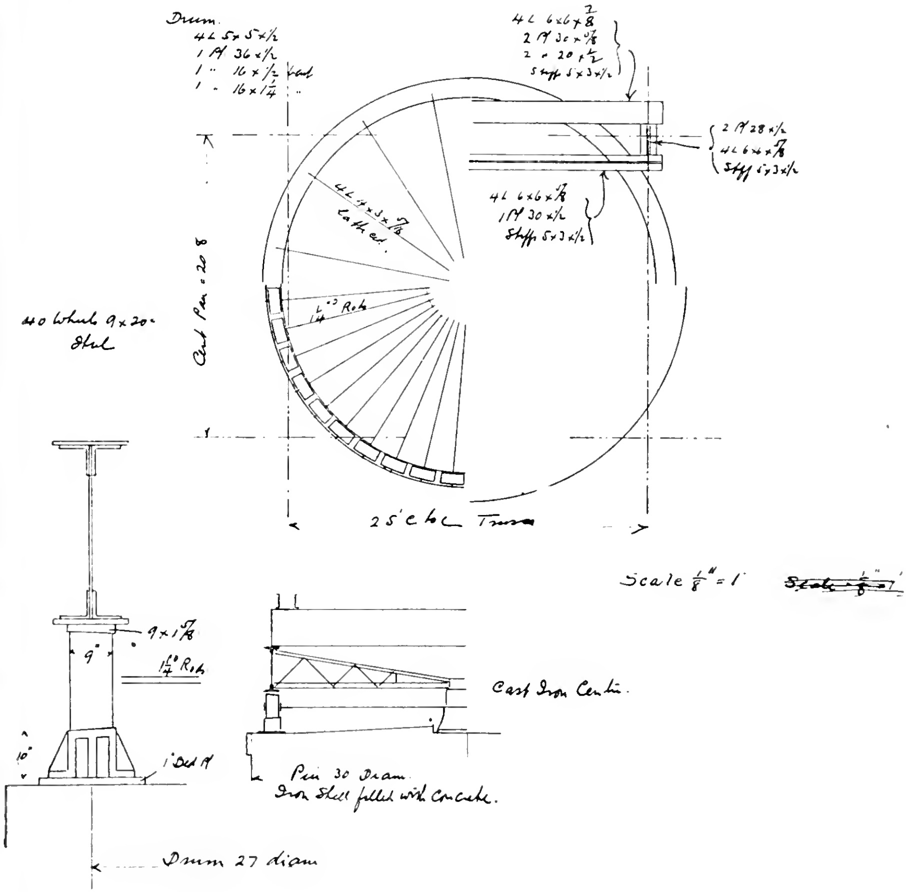


FIG 27

End Lifting Machinery.

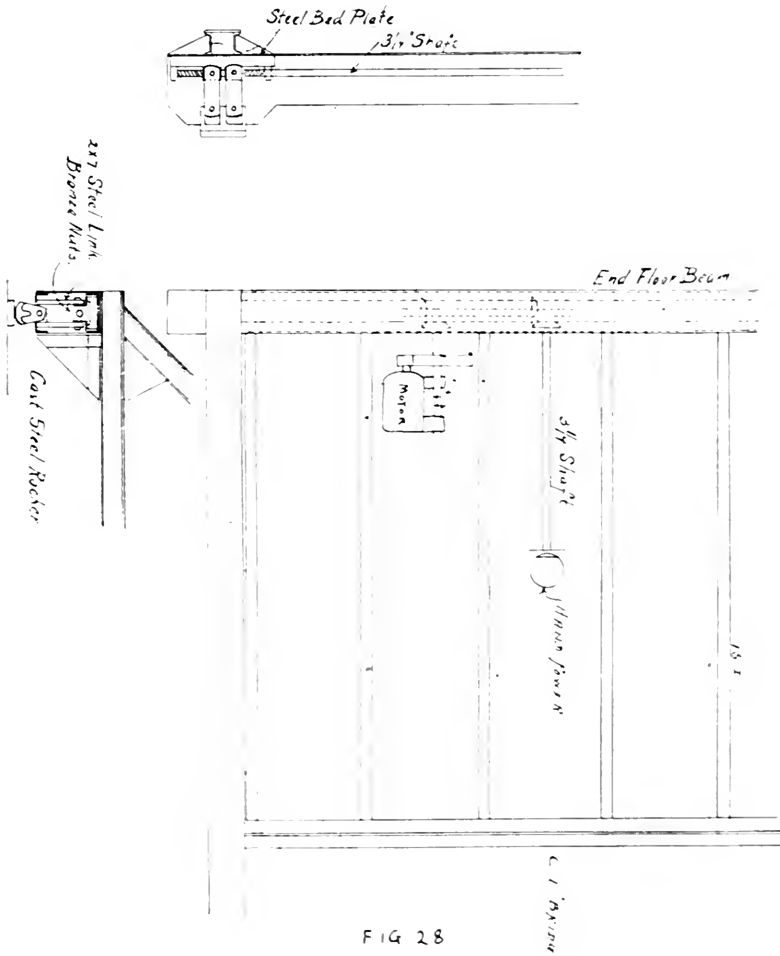


FIG 28

Weight of Turn-table.

2 Loading Beam	16356
2 " "	11218
Drum	20572
16 Drum Struts	9056
Machinery Box	3871
Bed Plates	7288
40 Wheel Rods	1900
4 × ½ Wheel Bars	1360
2 Centre Discs	1360
4 Loading girders	5644
Wt. of T. T. without machinery	78625
Rack and Track	25500
40 Wheels 20 × 9 in.	18000
Centre Machinery	13900
2 Sets end Machinery	15600
	73000

3 electric motors, 30 H. P. with rigging for operating same.

Besides these, there is required submarine cables, track rails, operator's house in tower, signals, gates, etc.

Summary of Weights.

Bridge proper	338000
" Joist	84000
Turn-table	78600
Machinery	73000

Total wt. of Metal 573600 44 lbs. per sq. ft. of floor and walks. This weight per sq. ft. of floor agrees very nearly with my formulæ for weight of drawbridges, which is weight per sq. ft.

$$3 + \frac{\text{Total Span}}{8}$$

The Madison Street Bridge.

7 fixed spans @ 190 - - -	1330 feet
1 draw span - - - - - -	316 "
Total length - - - - - -	1646 "

HANDLING DAYLIGHT

W. J. WITHROW.

It is with extreme pleasure that I have the privilege of standing on this platform once more after the elapse of over a decade.

Prismatic lighting, to the consideration of whose properties I invite your attention this afternoon, is of engineering interest, not so much on account of any abstruse calculations, as for its proved usefulness as a new application of certain well known laws of Optics to the practical lighting with daylight of dark interiors. At the risk of mentioning a good deal that is familiar to you, I will endeavor clearly to outline the general principles governing the use of this light-bending window glass.

As you all know, a light ray travels in a straight line through a uniform transparent medium, such as air at a constant density, but alters its direction on passing obliquely into a medium of different density. This may be well represented by considering a company of soldiers marching on even ground and striking obliquely the edge of a ploughed field. The end of the company entering the soft ground first is held back, while those still on firm ground, keeping up their old speed of marching, swing their end ahead. If the company still marches at right angles to its front it now moves in a new direction, more nearly at right angles to the line of demarcation between the firm and the soft ground. The greater the difference in the ground, the greater the change of direction, and the sharper the angle at which the company strikes the edge of the soft ground the greater the resultant change of direction. On moving from soft ground to hard again the operation is reversed—*i.e.*, the first files out move faster, thus swinging the company around more nearly parallel with the edge of the soft ground. One can easily imagine the company emerging at such a sharp angle that the first files out would swing their end so far ahead as actually to double back into the field. This will be referred to later on when considering total internal reflexion of light.

This, though an unscientific demonstration yet clearly illustrates the fundamental law of Optics, which forms the basis of prismatic lighting, viz.—the sine of the angle of incidence equals the sine of the angle of refraction multiplied by a constant. The particular constant for any two bodies varies with the difference in their relative densities and to a minor extent possibly with their other properties.

In Fig. 1. I, the angle of incidence, is the angle between the incident ray of light i and the perpendicular A Z to the surface

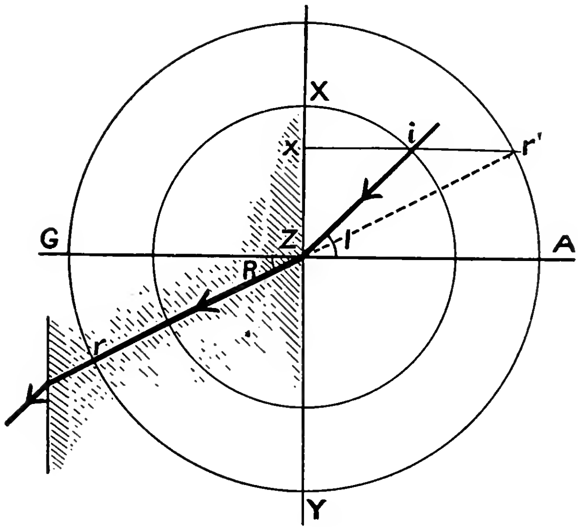


FIG. 1.

X Y of contact between the two transparent media through which the ray passes, and R, the angle of refraction, is the angle between the refracted ray r Z and the same perpendicular A Z G produced.

It is found that for air and flint glass, such as is used in the manufacture of prisms, the constant a equals 1.53, consequently the refractive power of this glass in air may be stated thus—Sin I = 1.53 Sin R.

Or, to express this graphically, see Fig. 1. In the plane X Y, between the body of air A and the body of glass G, at the centre Z, describe two circles X i and Y r at distances relatively of 1 and

1.53. Let i Z be any incident ray of light piercing the plane X Y from the body of air A at the point Z and cutting the circle X i at i. Through i draw x i r′ perpendicular to the plane X Y, cutting the circle Y r at r′ and the plane X Y at x—then r Z r′ produced will be the direction and sense of the refracted ray, i Z A the angle of incidence and G Z r the angle of refraction, and Sin i Z A =1.53 Sin G Z r.

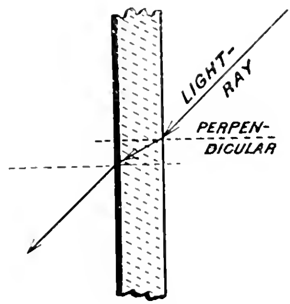


FIG. 2.

A ray of light passing from glass to air would require the constant a to be 1.53, and investigation would show that on passing through a surface parallel to the plane X Y into the air again, the ray would be bent back to its old direction. This is what happens with plate glass, see Fig. 2. If, however, it pass out of the glass through a plane inclined to the first it will assume a new direction, see Fig. 3. This latter is what happens with prisms.

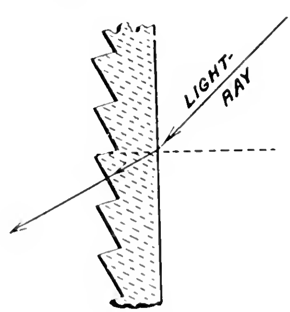


FIG. 3.

If both surfaces were made continuous one edge of the wedge so formed would be very thick, and the whole too heavy for use

in a window, see Fig. 5. One surface of a prism plate is therefore made in a succession of inclined planes forming a series of small wedges instead of one large one. By increasing the angle between the two surfaces of the prism plate the divergence of transmitted

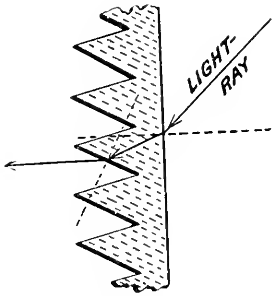


FIG. 4.

light would be increased, see Fig. 4. For this reason prism plates are made with different inclinations varying by 5° in the several plates of the series. These plates are made 4″ square, as larger sizes cannot be sharply moulded, and are strongly glazed together

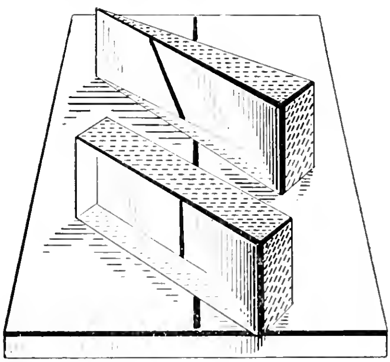


FIG. 5.

in copper by a patented electrolytic process to form large sheets of any required shape.

In order to bend incident light laterally, two complete series of prism plates are manufactured with the prism tilted up, one to the right, and the other to the left, at an angle of 22½°. By placing a right tilted prism on its side, we get a left tilt of 67½°,

asd reciprocally with the left tilt prism. By tilting an ordinary prism plate half way to right or left, we obtain 45° right or left tilts, whereas tilting it completely to right or left we get right or left tilts 90°.

With this range of prism plates and certain cases of using the prisms inside-out, light from any source, falling upon a window, may be directed to any part of the interior.

Having considered the theory of prisms, we will now consider their application.

Stand any place in a room. Look out through the window. The part of the room where you stand is primarly lighted from that particular part of the outside world that you can see. If you see a dark wall, you will be in the dark—if you see a bright sunlit or white washed wall, or generally better still—the open sky, then where you stand will be well lit, if, of course, the window space is large enough for the room.

This primary lighting is more or less modified by light reflected to you from any particularly well lit part of the same room. If a bright sunlit pavement outside throws a strong light on the ceiling near the window, the reflected light therefrom may make the whole room bright. Or, if the sun shines directly through the window for a part of the day, the interior may be rendered light throughout by reflection from the spot on the floor or wall where it shines, or by radiation from a translucent blind or window.

Generally speaking, however, the sky space, as seen from the window, is by far the brightest source of light available for illuminating the interior.

If, as generally happens—particularly in our more congested city districts, the bright sky is cut off by some obstruction opposite the window, such as a building, trees, etc., then the usefulness of prisms comes into play. Here, with ordinary window glass, the bright light from a more or less confined sky-space above falls bright and clear upon the floor immediately inside the window, where it is mainly absorbed by the non-reflecting carpet, dark flooring or furniture, and the rear of the room is left dark and

more or less gloomy, see Figs. 6 and 7. If, now, the window, frequently, merely the upper part, be glazed with prisms of a refracting angle merely sufficient to bend the light from the sky immediately over the top of the building opposite, sending it horizontally or slightly upwardly back through the room, then all the rest of the light from the sky up to the zenith will be spread equally along the rear and side walls and across the floors toward the window, giving an even illumination throughout.

In order to get a satisfactory result in each case, it is, of course, necessary to instal a sufficient area of prisms to suit the size of the room and the available sky space outside.

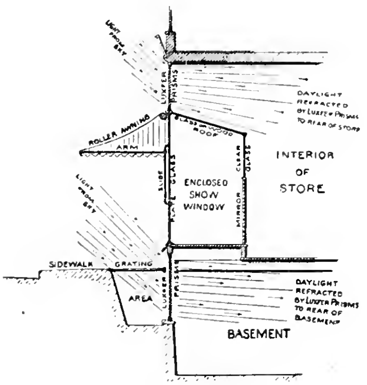


Fig. 6.

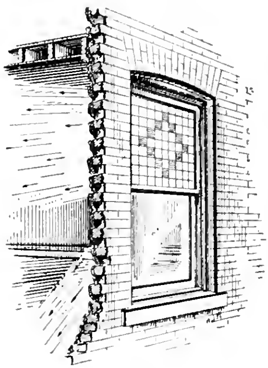


Fig. 7.

Some of the refinements of prismatic lighting which may make or mar its efficiency—I shall now briefly indicate.

If a very high building opposite has a low one, or none at all, close to right or left, then the use of one of the tilted prisms will draw light from the open side, bending it back into the room with greater illuminating effect than could be obtained by drawing light from the narrow band of sky seen over the top of the building. If the space above is extremely narrow, as in narrow lanes between buildings, or in light wells, the light may fall so steeply that the usual vertical window intercepts very little of it. In this case a canopy of prisms is hung outside in front of the upper part

of the window, see Fig. 8. Any of the various forms of prisms mentioned above may be used here if the refracted light is required to be thrown merely a short distance into a room to light desks or other articles near the window. Prisms can only be adapted to refract light up to about 60°, in fact anything beyond 45° of refraction begins to loose in brilliancy.

If, on the other hand, the almost vertically falling light is required to be thrown horizontally back into a room, the principle of refraction will not answer. In this case a form of prism is used in which the light entering the plane surface falls upon an inner

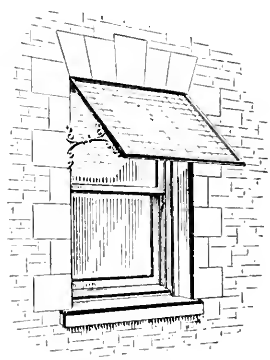


Fig. 8.

surface at such an angle as to cause its total reflexion. This surface will reflect with all the brilliancy of a silvered mirror, throwing the light into the room through the third surface of the prism.

For sidewalks this principle is adopted—the Standard prism, has two unequal downwardly projecting prisms of unequal angle, so adapted as to throw light falling vertically downward inwardly toward the basement—the unequal points being introduced to prevent the reflected light from being stopped by the next prism point in front. See Figs. 9 and 12.

A later and better form is the Multiprism, which has a single downwardly projecting wedge, having its reflecting and inward transmitting surfaces curved so as to cause the light reflected from

the different parts of the surface of one prism to successively pass as close to the bottom of the next prism as possible. These prisms

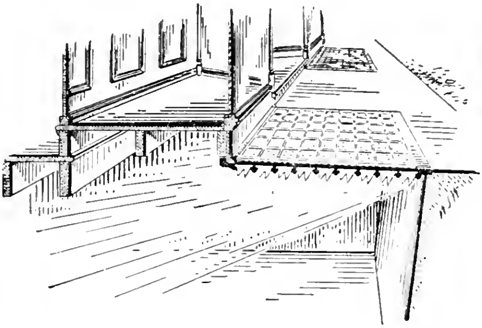


FIG. 9.

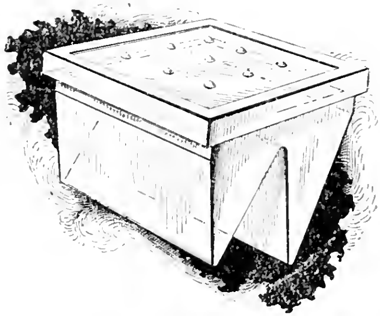


FIG. 12.

are set brick fashion, so as to break joints, and from the basement give the appearance of an unbroken sheet of light. See Fig. 10.

Where a stringer, joist or other inside obstruction on the basement ceiling, prevents the pavement prisms from throwing their light back to the rear of the cellar, a curtain of window

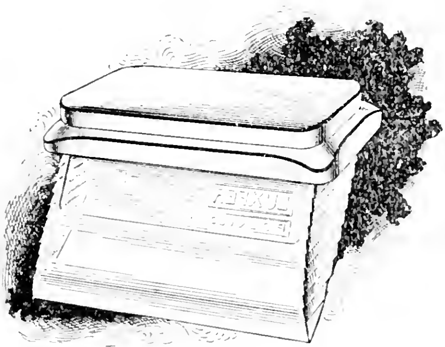


FIG. 10.

prisms of slight refractive power near the top increasing to high refractive efficiency at the bottom, is hung between the pavement prisms and the cellar. This curtain gives a second refraction to the light from the pavement illuminating the whole interior to the rear. This form of curtain works well in open areas where traffic does not necessitate the use of pavement prisms.

All these prism panels, pavement and window, light not merely the space in front of them, but fan-out their light sideways in exactly the same proportion as the sky space from which they derive their light is spread laterally.

In the case of window prisms, if there is a heavy overhang or reveal, the upper prisms would be over-shadowed and useless. In this case the prism panel is either hung in a separate wooden

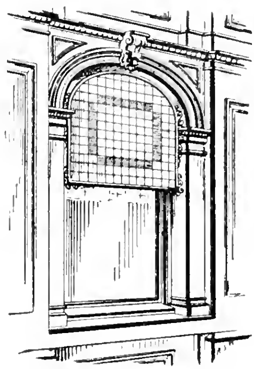


Fig. 11.

or ornamental iron frame out near the front of the wall or cornice, see Fig. 11. A more recent way is to remove the upper part of the window, placing the prisms in a closed frame near the front of the wall, and uniting the bottom of the prisms with the deep-set lower part of the window by a transom bar, in which is installed a ventilating device.

AIR BRAKES.

W. E. Foreman.

The subject of "Air Brakes" is so broad, that to properly describe it, a detailed description of each part, showing the improvements that have been made in each during the last few years ought to be given. But as I am both limited by time and space, a general description of the principal systems now in use is all that can be attempted at present. Besides the general description I would like to bring before you for consideration a few very interesting problems which are closely connected with this subject.

The "Air Brakes" has quite a long history, which forms very interesting and instructive reading. Many different forms of power brakes were in use in the early years of the last century. The most important of these were the "Chain Brake," and the "Hydraulic Brake." Then in the second half of the nineteenth century these were superseded by the "Vacuum" and "Straight Air." And again a few years after the introduction of the above, they in turn were also displaced by the Automatic Vacuum and the Automatic Air Brakes. The latter was invented by Mr. George Westinghouse in the year 1873, just four years after the introduction of the "Straight Air" brake. From year to year the above gentleman patented many improvements upon this latter form until it reached its present form of perfection.

The Vacuum Brake.

The Vacuum Brake, which at one time was the greatest rival the Westinghouse Company had to contend with, but which to-day is nearly extinct as far as this continent is concerned, we will consider just a moment. In principle it is diametrically opposite to that made use of in the Automatic Air Brake. The principle upon which this brake operates is as follows:—The train pipe, which extends the full length of the train, is always kept free of air; and when an application of the brakes is desired, the air at atmospheric pressure is admitted to the train pipe, and sets a valve in such a position that one side of the brake diaphragms is directly

connected to a reservoir from which the air is exhausted. The excess pressure on the other side of the diaphragm which is exposed to the atmospheric pressure, forces the diaphragms forward and applies the brakes. To release the brakes, the air is again exhausted from the train pipe, and the valves and brake diaphragms take or return to their normal positions.

The following apparatus comprise the Automatic Vacuum Brake:—

1. The ejector, the function of which is to maintain the vacuum in the train pipe and brake diaphragms.

2. A continuous train pipe line with hose couplings between each car.

3. Brake diaphragms from which the air is exhausted, causing the pressure of the atmosphere to force the rubber disks into the iron shell and set the brakes.

3. The reservoir, in which a vacuum is maintained, and into which the air is constantly exhausted from the diaphragms.

6. Finally the valve which forms the connection between the reservoirs and the diaphragms. Its objects are to control the passage of air from the brake diaphragms to the reservoir, and partially or wholly apply the brakes.

In Fig. 1, is shown the Eames' Automatic Vacuum Brake, which ranks among the first of this kind.

The "Quick Action Automatic Brake," which is a decided improvement on the previously mentioned "Automatic," was first introduced shortly after the Master Car Builders' braking tests, conducted at Burlington during the year 1887. It is in use on all railroads in America; and in England and the continent it is fast driving its competitors from the market. The Westinghouse Company have equipped by far the largest proportion of trains with their system. The New York Company are second, while the percentage of cars equipped with other systems is so small as to be negligible.

The following general description of the operation of the Air Brake will apply equally as well to the New York Company's as to the Westinghouse, since the apparatus for each system fulfil the same functions and only differ in construction.

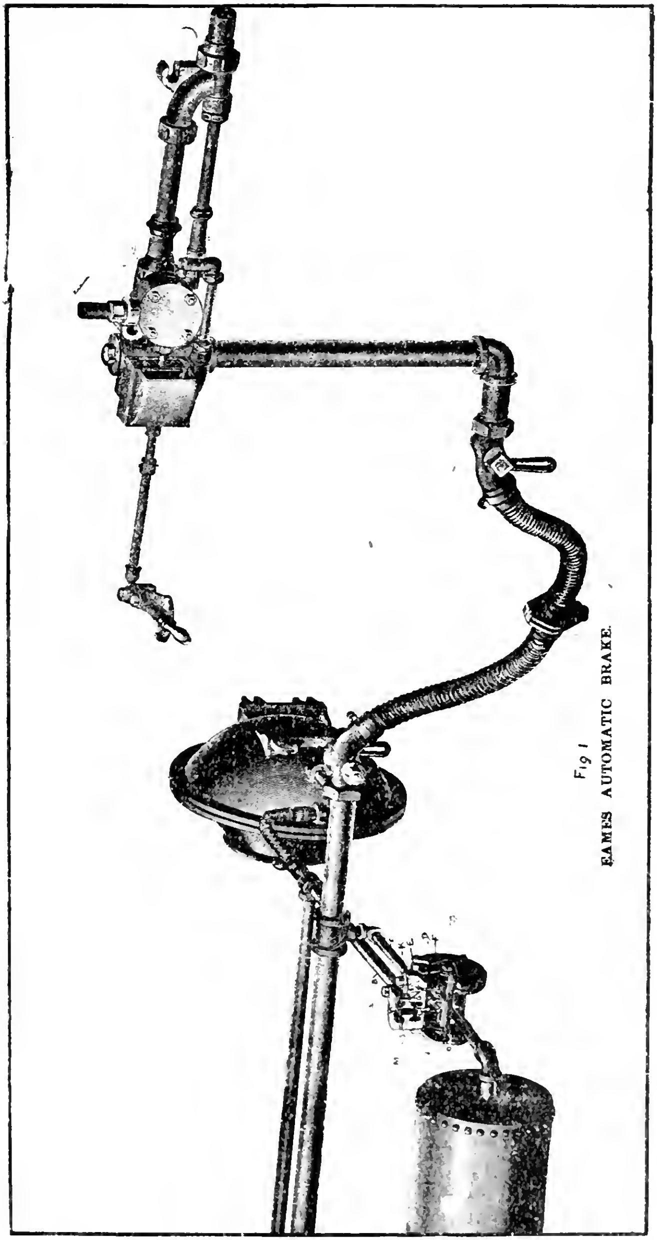


Fig 1
EAMES AUTOMATIC BRAKE.

The air, compressed by the pump, is first delivered into the main reservoir. From there it flows to the engineer's valve; thence through the train pipe to the triple valve on each car, passing through the latter to the storage or auxiliary reservoirs. During normal conditions of running, the train pipe and reservoirs, excepting the main reservoir on the engine, contain air under a pressure of 70 lbs. per square inch. With the engineer's valve, changes of pressure in the train pipe are made, causing the triple valves to operate either to apply or release the brakes.

Moving the handle of the engineer's valve a specified distance permits air from the train pipe to escape, thus reducing the pressure therein. This reduction of pressure operates the sensitive triple valve, which then allows air to pass from the auxiliary reservoir to the brake cylinder, forcing the brake piston in the direction to apply the brakes.

To release the brakes, the engineer's valve is moved back to its running position, and the train pipe pressure is then raised to 70 lbs. per sq. in. This increase in train pipe pressure causes the triple valve to reverse its position, closing the connection between the auxiliary reservoir and the brake cylinder, allowing the air from the latter to escape to the atmoshpere. The brake piston then returns to its running position, and the brakes are thus released.

The Westinghouse and New York Quick Action Automatic Air Brakes consist of the following principal parts:—

1. The compressor or pump which compresses the air.

2. The main reservoir in which the compressed air is stored.

3. The engineer's equalizing and discharge valve, which regulates the flow of air into the train pipe and auxiliary reservoirs for charging the train and releasing the brakes, and from the train pipe to the atmosphere for applying the brakes.

4. The train pipe, which leads from the engineer's valve throughout the train, supplying air to the auxiliary reservoirs.

5. The brake cylinder which has its piston connected to the brake levers, in such a manner that the brakes are either applied or released according as the piston moves in or out.

6. The quick action automatic triple valve, with which each car is equipped. The valve controls the admission of air from the auxiliary reservoir to the brake cylinder, the discharge of air from the brake cylinder to the atmosphere, and the admission of air from the train pipe to the auxiliary reservoir.

7. The auxiliary reservoir, which stores upon each car sufficient air to operate the brakes upon that car.

8. The pump governor, which regulates the supply of steam to the pump, automatically stopping the supply or steam when the pressures in the train pipe and reservoirs have reached the desired point.

9. The hose couplings, which connect the train pipe of one car to the train pipe of the next.

10. The duplex air gauge, which indicates on one scale the pressure in the train pipe, and on the other the pressure in the main reservoir.

11. The conductor's valve, which is operated by that individual when he wishes to apply the brakes.

Westinghouse High Speed Brake.

The Westinghouse High Speed Brake is another form or modification of the Automatic just described, and which is used on trains which run at very high speed, such as the "Empire State Express" and "Congressional Limited." This brake consists of the quick-action, with the addition of an automatic pressure reducing valve. One of these valves is connected to each brake cylinder, and the air pressure supplied to the train pipe and auxiliary reservoirs considerably increased. In ordinary service application the valve remains inoperative, unless the pressure in the cylinder exceeds a certain fixed limit (usually sixty pounds), when it then operates to discharge air from the cylinder until the fixed limit is again reached, and then ceases to discharge air from the cylinder. The reason for this variation of the brake cylinder pressure, is that at high rates of speed greater pressure can be exerted on the wheels without causing them to skid, than can be exerted on wheels revolving at a low velocity. Consequently, as the speed of the train is materially reduced, the pressure in the

brake cylinder has also been reduced. We have thus increased the retardations during the early part of the stop, while running no danger of skidding the wheels. Trains can be stopped by this brake, when they are running at the rate of sixty miles an hour, in about 450 feet shorter distance than when they are equipped by the ordinary Quick Action Automatic Brake.

The triple valve is the most important link in the whole air brake system. On it we depend for the rapidity of the application of the brakes. If, for one short instant it fails to operate, when required, the brakes on that car are inoperative.

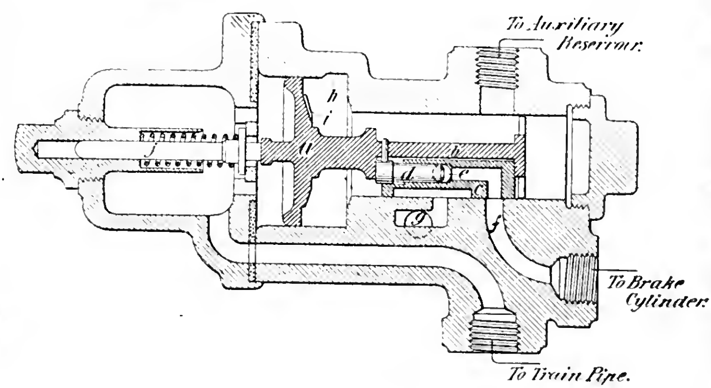


FIG. 2. THE PLAIN TRIPLE-VALVE.
In Service Position. Brakes Applied.

The triple valve has undergone many changes and improvements before it reached its present forms. The first valve was invented by Mr. George Westinghouse, Jr., in 1872, and the last shortly after the Burlington tests in 1887.

Before describing the valve we must understand why they are called triple valves. It performs the triple function of (1) Admitting air from the train pipe to the reservoir, for the purpose of charging it with air under pressure. (2) Admitting air from the reservoir to the brake cylinder, for the purpose of applying the brakes, and (3) Establishing communication between the

brake cylinder and the atmosphere for the purpose of discharging the air from the brake cylinder and releasing the brakes.

There are two Westinghouse Triple Valves, the plain Automatic, which is used in ordinary service applications, and the Quick Action Automatic, which is designed both for service and emergency applications. This latter valve is simply a plain triple

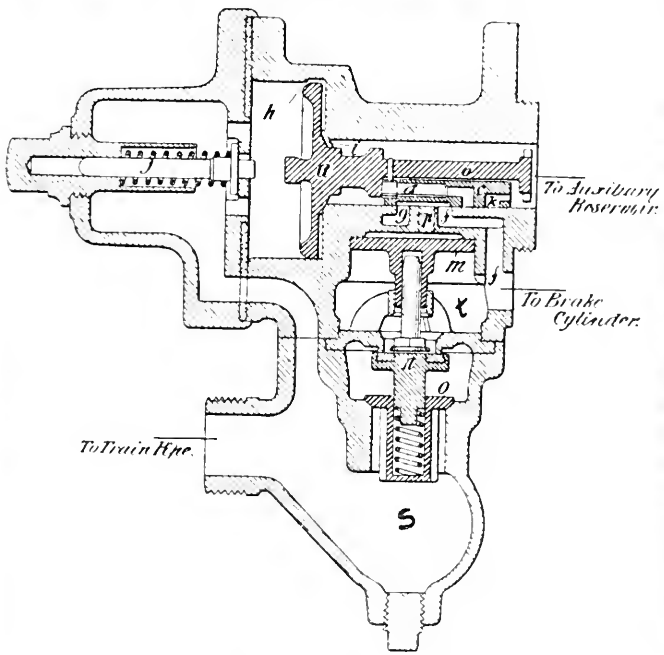


FIG 3 QUICK-ACTION TRIPLE VALVE.
Normal Running Position Brakes Released

with the addition of a few more valves which render it more efficient in emergency applications than the plain triple.

Fig. 3 is a drawing of the Westinghouse Quick Action Automatic valve, with its parts in the normal running position with brakes released. If the part p, and the chambers below it, s and t, were removed, the valve would be transformed into a plain triple.

The emergency parts of this valve are then, the chambers s and t, the piston m, and the valves n and o. The locations of the pipe connections to the train pipe, the auxiliary reservoir, and the brake cylinder are clearly indicated. A piston, a, is adapted to move backward and forward, while its stem, b, extends forward into a somewhat smaller valve chamber containing a slide valve e, which is loosely confined between two shoulders upon the piston stem. In the interior of the slide valve e, is a small poppet valve, d, called the graduating valve, which is secured by a pin to the piston stem b.

In the position of the parts shown in fig. 3, the compressed air from the train pipe enters through the passage ways and chamber on the outer side of piston a (to the left). Then it passes around the piston, through the feed grooves h and i into the valve chamber, from which it passes directly to the auxiliary reservoir. This reservoir is thus kept charged with air at the same pressure as the train pipe line.

When the engineer makes a service application, he reduces the train line pressure about five pounds by discharging a portion of the air. This lessens the pressure upon the outer face of the piston a, and the excess pressure upon the other side forces the piston to the left, at the same time closing the feed grooves h and i, thus cutting off all communications with the train pipe, and simultaneously withdraws the graduating valve d, from its seat in the slide valve. The shoulder at the end of the piston stem b, then comes in contact with the end of the slide valve e, which is thereafter moved along with the piston in its outward progress, which is finally arrested by contract with the stem j. Then the part e is over the passageway f, and the air from the auxiliary reservoir has a clear passage to the brake cylinder. The part e extends transversely through the slide valve and conducts air from the auxiliary reservoir into the passageway in the slide valve, which has now been uncovered by the outward movement of the graduating valve d. The discharge of air from the auxiliary reservoir to the brake cylinder is accompanied by a reduction of the air pressure in the auxiliary reservoir and the valve chamber of the triple valve, which continues until the pressure is slightly lower

than that of the air remaining in the train pipe, and at the chamber at the outerside of the piston a. The slight preponderance of pressure on the outside of the piston causes it to move inwardly until the graduating valve d becomes seated in the slide valve. The piston is prevented from moving any further by the frictional resistance offered by the slide valve and its seat. Upon the closing of the graduating valve d, communication between the brake cylinder and the auxiliary reservoir is shut off, and the brakes remain applied with so much force as is due to the compressed air which has already been admitted into the brake cylinder.

If the engineer finds that he needs more braking force, he makes a further slight reduction in the train pipe, and the above operation is again repeated, admitting a further quantity of compressed air to the brake cylinder. This operation is called graduating, and entirely depends upon the proper working of the graduating valve d.

The above description applies both to the plain and the quick action triples in service stops. In an emergency application of the quick action triple a considerable quantity of air is discharged from the train pipe, causing a great difference between the pressures on the sides or faces of the piston a. This preponderance of pressure on the inner face of the piston causes the piston a to travel outwardly with more force, compressing the spring on the stem j, until it is arrested by the end of the chamber. The passageway p, which admits the compressed air above the piston m, being thereby uncovered, instantly conducts the compressed air from the auxiliary reservoir to the upper face of the piston m, which forces that piston downward and thereby opens the emergency valve n, as shown in Fig. 4. It is to be observed that at this instant, (1) the brake cylinder is empty, no air from any source having yet entered it; (2) the air pressure in the train pipe, while having been reduced considerably below the pressure in the auxiliary reservoir is still great, and has, by merely lifting the valve o, a capacious and unobstructed passageway, around the emergency valve n, into the empty brake cylinder. Thus the air from the train pipe lifts the check valve o, and rushes into the brake cylinder, until the pressure in the brake cylinder and the train

pipe are equalized. Then the check valve closes, shutting off all connections between the train pipe and the chamber t. The air which has been admitted to the brake cylinder, increases the available braking force which may be obtained in the brake cylinder.

The effect of the discharge of air from the train pipe into the brake cylinder of the first car does not merely more quickly

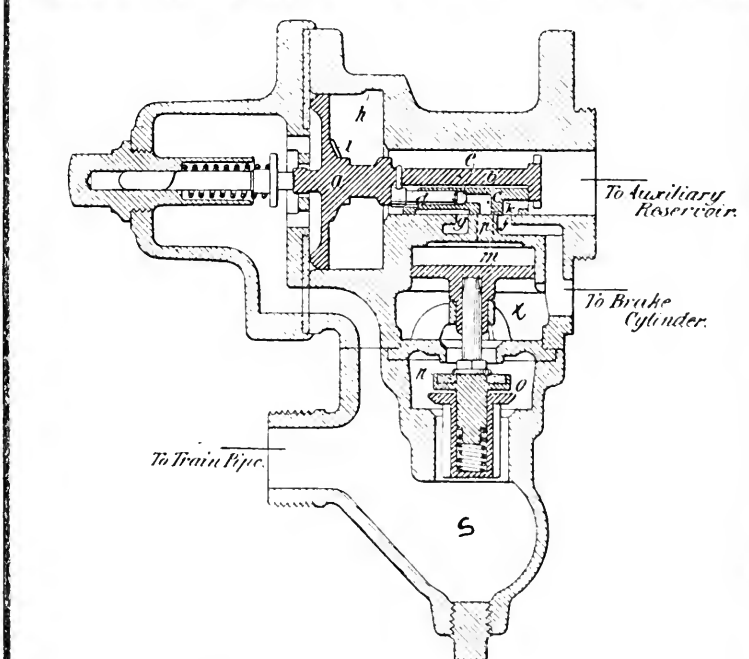


FIG. 4 QUICK ACTION TRIPLE-VALVE.
Emergency Position. Brakes Applied

and powerfully apply the brakes on that car, but also causes a sudden and material reduction of the pressure upon the outer face of the piston a, on the next car. Thus the action which is described above is greatly accelerated on the whole train, the first triple hastening the action of the second, and the second the action of the third, etc., throughout the whole train.

To release the brakes with both styles of triple, the train pipe is recharged to its normal pressure, which preponderance of pressure on the outer face forces the piston a, to its running position. At the same time the slide valve c, is carried to its position for running, as shown in Fig. 3, where a direct connection is made from the brake cylinder, through the passageway f, and exhaust port g, to the atmosphere. Thus the air being exhausted from the brake cylinder the brakes are released.

New York Triple.

The New York Air Brake have also both a plain triple and quick action triple. Like the Westinghouse they are both automatic in their action.

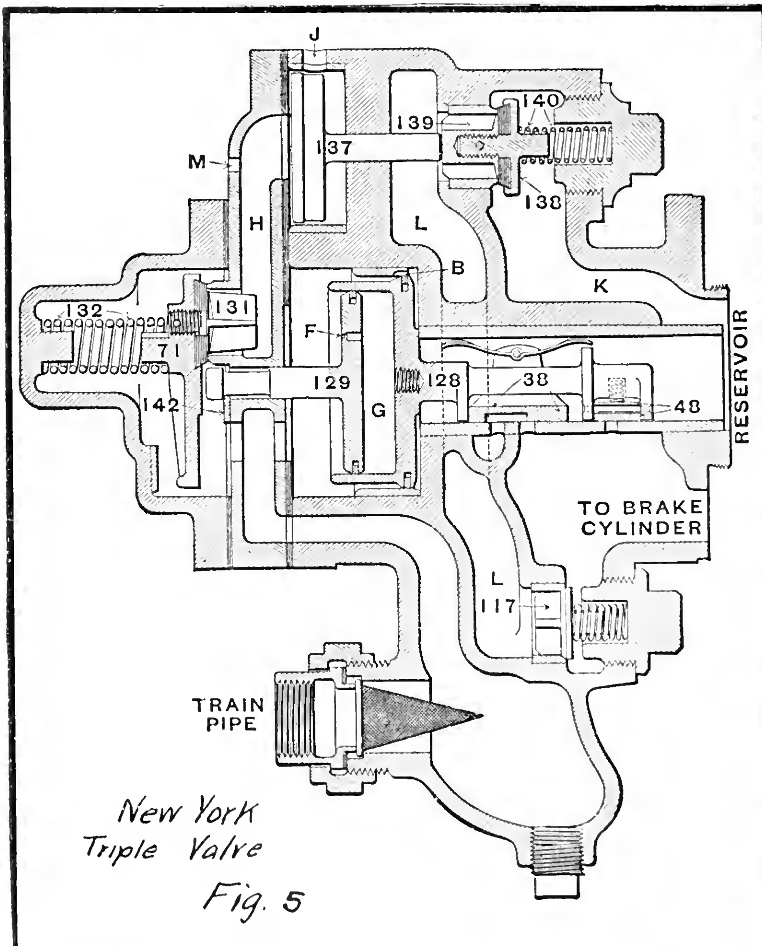
The quick action triple is shown in Fig. 5. The quick action parts occupy the left and top portions of the drawing, and remain inoperative under ordinary service applications. The service parts occupy the central portion of the drawing, the operation of these parts can be traced on the drawing which clearly indicates them.

"Referring to the figure, the vent valve 71 is held to its seat by spring 132, assisted by train pipe pressure, and can only be opened when piston 129 is forced to the left. Quick action valve 138-139 is held to its seat by spring 140, assisted by the reservoir pressure, and can only be opened when piston 137 moves to the right."

"Main piston 128 has the same stroke both for emergency and service applications, but is extended to form a cylinder in which piston 129 is fitted. Through piston 129 is a small opening F, allowing the train pipe air to pass through and equalize the pressure on both sides. The dimensions of this opening are such that when the main piston 128, moves slowly to the left, as in service applications, the air in space G will be forced through opening F without disturbing piston 129 from its position shown."

"A sharp reduction of train pipe pressure for an emergency stop will cause main piston 128 to move rapidly to the left. In this case air from space G cannot flow through passage F fast enough, and exerts a momentary pressure upon piston 129, strong enough to overcome its resistance and cause valve 71 to be forced

from its seat. This allows train pipe air to enter the passage H and escape to the atmosphere through holes J and M, while at the same time, it forces piston 137 to the right, which unseats valve 139 and allows the full power of the reservoir pressure



New York Triple Valve
Fig. 5

to be instantly effective in the brake cylinder through the large passageways K, L, and check valve 117."

"Meanwhile, as passage F is always open, the temporary pressure exerted by the air in chamber G, has rapidly lost its

effect, and spring 132 has returned valve 71 to its seat, thus stopping the escape of air when train pipe pressure is sufficiently reduced to properly apply the brakes. As valve 71 closes, it returns piston 129 to its original position. Valve 139 and piston 137 have also been returned to their former positions, as shown in the figure."

"Restoring the train pipe pressure causes the valves 38 and 48 to return to their normal positions as shown, allowing the auxiliary reservoir to be recharged, and the air to escape from the brake cylinder, thus releasing the brakes."

"The astonishing and almost inconceivable rapidity of the serial recurrence of quick-action triple value operation may be best appreciated by comparison with the rate of propagation of simple vibrations through a clear and quiescant atmosphere. The simplest illustration is that of sound, which, under ordinary conditions, travels at the rate of about 1,100 feet per second. The propagation of a sound disturbance to a distance of 2,000 feet in a quiet atmosphere, requires little more than 1.8 seconds. An emergency application of the brakes upon a fifty car train, wherein one piece of mechanism is caused to operate, thereby producing an impulse, which causes a second piece of mechanism to operate, and so repeated through fifty mechanisms with successive impulses, is serially propagated throughout the 2,000 feet in 2.5 seconds."

The increasing use of heavy and high speed cars in street car service, seems to make the application of the air brake even to single cars, a logical necessity. Under present conditions the manual labor and careful attention required by the hand-brake is so great, that the motormen are not able to retain control of their cars and make the most efficient stops. The principle of the air brake has been successfully adapted to the street cars.

The great difficulty in applying this style of brakes was the securing of compressed air. The air was finally compressed in two ways, first by attaching an eccentric, which worked an air compressor, to the axle of the car, and second by installing on the motor-car a rotary air pump driven by a motor. In the first

method about forty revolutions of the car wheels suffices to fill the reservoirs with air, at a pressure of 32 pounds. Having attained that pressure, a governor automatically cuts off in such a manner that the piston stops working against pressure. The motorman applies the brake by simply turning the controlling valve, which allows the air to enter the cylinder. Only three pounds of the storage pressure are required for each application. When the brakes are released and the car starts again, the piston once more operates against pressure to restore the reservoir pressure to 32 pounds; but by an automatic device this does not begin until the car has gathered headway. Then only five revolutions are required to recharge the reservoir to its normal pressure.

In the second method or system the running of the air pump and the maintenance of the reservoir at the desired pressure is entirely independent of the speed of the car. The pump is driven by a motor which is supplied with electricity from the trolley wire. The current to the motor is automatically turned on or shut off as the reservoir pressure drops below or attains the desired pressure. Besides the motorman has control of the current supply to the motor if desired.

An important subject or division of this topic, is the relations which exist between the various forces which are brought into existence by an application of the brakes. Some of the problems which we will now discuss, bearing on this subject, are: first, the transfer of weight from the rear to the front truck during an application of the brakes; second, the transfer of a certain percentage of the weight borne by each pair of wheels of a four wheel truck when unbraked, from the rear to the front wheels when the wheels are braked; third, the relation between the brake shoe friction and the rail friction; fourth, the proper angle at which to hang the brake shoes, so that the brake shoe pressures may approach, as near as possible, those theoretical relations or values which we will determine in Problem I.

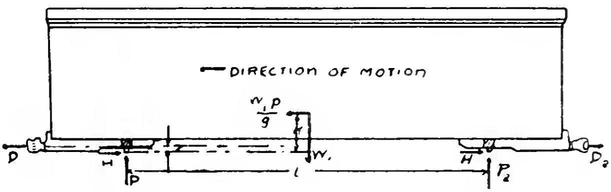
These problems were first discussed by Mr. R. A. Parke, who read a paper before the New York Railway Club in 1897, giving his views and solutions of the foregoing problems. He thus proceeded to consider and solve Problem I.

Problem I.

To determine the proportionate weight which each truck sustains during an application of the brakes.

We will represent the car with its trucks removed by Fig. 6. The force which each truck exerts upon the car body is indicated by an arrow. This force must be exerted through the centre plate of each truck. In this case we are considering only the case where the brake shoes are hung from the trucks. Brake shoes are so seldom hung from the car body that their discussion is not very profitable.

Fig 6



Let P_1 = the supporting force from the forward truck, which is of course the same as that portion of the weight of the car body which is born or carried by that truck.

P_2 = the supporting force from the rear truck.

H = the retarding force exerted upon the car body, through the centre plates, to reduce the energy of the car body due to its velocity and slacken its speed. We assume that the braking force applied to each truck is the same.

D_1 = the pull upon the draw bar. This quantity is generally a positive quantity when the car is empty and braked to its full

capacity and a locomotive attached ahead. Sometimes this force may become negative when the cars ahead push back upon the draw bar, or the unbraked cars in the rear are pushing this braked car into those ahead.

D_2 = the backward pull on the rear draw bar. This may be a positive quantity due to the action of the cars ahead or may be negative due to the action of the cars behind.

W_1 = the weight of the car body, acting through the centre of gravity of the car body.

l = the distance from centre to centre of the trucks.

k = the distance the centre of gravity is vertically above the point of contact of the truck and the car body.

z = the distance the centre line of the draw bar is above the point of contact of the car body and the truck.

g = the acceleration of gravity.

p = the negative acceleration or retardation due to an application of the brakes.

Now the forces acting upon the car in a horizontal direction are D_1, D_2 and the two forces H. Therefore the total effective resistance to the forward motion of the car body is $2H + D_2 - D_1$. Each particle of the car is subjected to a retardation p, and thus the total retarding force is equivalent to the mass of the car body multiplied by p, or an imaginary force $\frac{W_1}{g}p$, acting through the center of gravity of the car. The energy of the car due to its velocity is opposed to the retarding force $2H + D_2 - D_1$; and thus the force $\frac{W_1}{g}$ p is equal and of opposite sign to the retarding force, and their algebraic sum is zero. That is

$$2H + D_2 - D_1 = \frac{W_1}{g}p\,; \text{ or } H = \frac{W_1}{2g}p + \frac{D_1 - D_2}{2}. \tag{1}$$

Taking the algebraic sum of the moments of the forces, real and imaginary, about the point of intersection of the forces H and P, at the front centre plate,

$$P_2 l + (D_1 - D_2)z + \frac{W_1}{g}pk - W_1\frac{l}{2} = 0,$$

From which we get

$$P_2 = \frac{W_1}{2} - \frac{W_1}{g} \frac{k}{l} \cdot p - (D_1 - D_2)\frac{z}{l}. \tag{2}$$

Similarly by taking moments about the point of intersection of the forces H and P_2 at the rear center plate we get,

$$P_1 = \frac{W_1}{2} + \frac{W_1}{g} \frac{k}{l} \cdot p + (D_1 - D_2)\frac{z}{l}. \tag{3}$$

Now, $D_1 - D_2$ can never be a negative quantity. And z, even if it is negative, is always very small. Therefore from the two equations for P_1 and P_2, it is evident that the sustaining force P_1 is always greater that the sustaining force P_2 during an application of the brakes. Or that portion of the weight of the car body supported by the forward truck during an application of the brakes is greater than that supported by the rear trucks.

Therefore to avoid skidding the wheels, consideration of the rear truck which bears the least weight is only necessary. This brings us to the second problem, namely the conditions which prevail on the rear truck during an application of the brakes. To simplify our calculations we will let the algebraic difference $D_1 - D_2 = D$. Then the force with which each truck retards the car body is

$$H = \frac{W_1}{g} p + \frac{D}{2}. \tag{4}$$

Also substituting the value D for $D_1 - D_2$ in equation (2) we get

$$P_2 = \frac{W_1}{2} - \frac{W_1}{g} \cdot \frac{k}{l} - \frac{D}{2} \frac{z}{l}. \tag{5}$$

which is the portion of the weight of the car body carried by the rear truck during an application of the brakes.

Problem II.

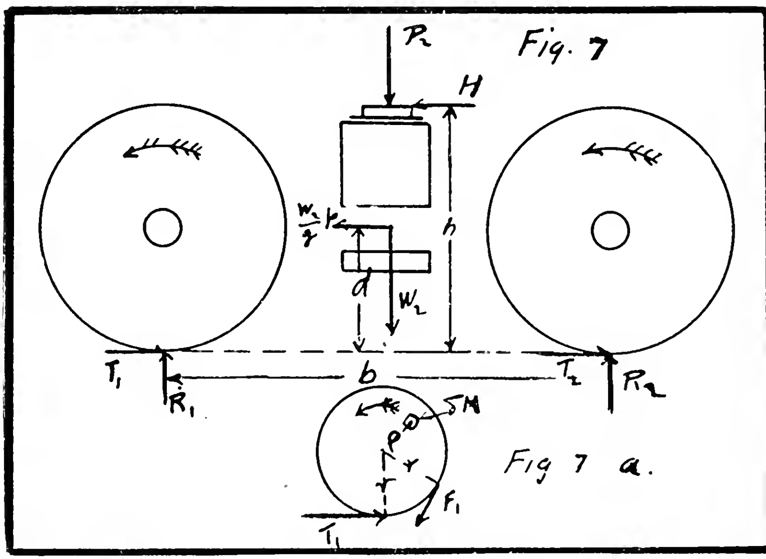
To determine the conditions existing at the rear truck during an application of the brake.

The skeleton of the truck is shown in Fig. 7. The various forces which act on the truck are indicated, and defined as follows:—

R_1 = the pressure of the forward pair of wheels on the rails.

R_2 = the pressure of the rear pair of wheels on the rails.

T_1 = the retarding frictional force applied by the rails to the forward pair of wheels, and keeps up their continued rotation in spite of the friction of the brake shoes.



T_2 = the retarding frictional force applied by the rails to the rear pair of wheels, and keeps up their continued rotation in spite of the friction of the brake shoes.

P_2 = the pressure of the car body upon the rear truck. We obtained the value of this in Problem I.

H = the force with which the car body drags the truck forward. This we also obtained in Problem I.

h = the distance between the point of contact of the car body and the truck, and the top of the rail.

d = the distance the center of gravity is above the top of the rail.

b = the base of the truck.

W_2 = the weight of each complete truck.

Each particle of the truck suffers a retardation p, and the total retarding force absorbed by the truck is equal to the mass of the truck multiplied by p or $\frac{W_2}{g}p$. And this imaginary force acts at the center of gravity of the truck in opposition to the retarding forces, and must be the equivalent of the difference between the sum of the retarding forces $T_1 + T_2$ and the force H which urges the truck forward. Thus,

$$T_1 + T_2 - H = \frac{W_2}{g}p \ldots . \qquad (6)$$

Now taking the algebraic sum of the moments of the real and imaginary forces, first about the point of contact of the rear pair of wheels and the rails, we get

$$Hh + W_2\frac{b}{2} + P_2\frac{b}{2} + \frac{W_2}{g}pd - R_1b = 0.$$

Then taking moments about the point of contact of the forward wheels and the rails we derive—

$$Hh - W_2\frac{b}{2} - P_2\frac{b}{2} + \frac{W_2}{g}pd + R_2b = 0.$$

Substituting in the last three equations the values of H and P_2 already determined, the equations become respectively:—

$$T_1 + T_2 - \frac{W_1}{2g}p - \frac{D}{2} = \frac{W_2}{g}p,$$

$$\frac{W_1}{2g}ph + \frac{D}{2}h + W_2\frac{b}{2} + \frac{W_1}{2}\frac{b}{2} - \frac{W_1}{g}\frac{k}{l}p\frac{b}{2} - D\frac{zb}{12} + \frac{W_2}{g}pd - R_1b = 0,$$

$$R_2b + \frac{W_1}{2g}ph + \frac{D}{2}h + \frac{W_2}{g}pd - W_2\frac{b}{2} - \frac{W_1}{2}\frac{b}{2} + \frac{W_1}{g}\frac{K}{l}\cdot p\cdot\frac{b}{2} + D\frac{z}{l}\cdot\frac{b}{2} = 0.$$

From the first of these equations

$$p = \frac{2T_1 + 2T_2 - D}{W_1 + 2W_2}g. \qquad (7)$$

Again, substituting in the second and third of the above equations the value of p and collecting similar terms, we get—

$$\frac{W_1\left(h - \frac{bk}{l}\right) + 2W_2d}{W_1 + 2W_2}(T_1 + T_2) + \left\{\frac{W_1\left(\frac{bk}{l} - h\right) - 2W_2d}{W_1 + 2W_2} + h - \frac{bz}{l}\right\}\frac{D}{2}$$

$$+ (W_1 + 2W_2)\frac{b}{4} - R_1b = 0.$$

$$\frac{R_2b + W_1\left(h + \frac{bk}{l}\right) + 2W_2d}{W_1 + 2W_2}(T_1 + T_2) + \left\{h + \frac{bz}{l} - \frac{W_1\left(h - \frac{bk}{l}\right) + 2W_2d}{W_1 + 2W_2}\right\}\frac{D}{2}$$

$$-(W_1 + 2W_2)\frac{b}{4} = 0.$$

Solving these equations for R_1 and R_2 respectively, substituting for $W_1 + 2W_2$, the complete weight of the car, body and two trucks, the term W,

$$R_1 = \frac{W}{4} + \frac{W_1\left(\frac{h}{b} - \frac{k}{l}\right) + 2W_2\frac{d}{b}}{W}(T_1 + T_2) + \frac{W_1\frac{k - z}{l} + 2W_2\left(\frac{h - d}{b} - \frac{z}{l}\right)}{2W}D$$

$$R_2 = \frac{W}{4} - \frac{W_1\left(\frac{h}{b} - \frac{k}{l}\right) + 2W_2\frac{d}{b}}{W}T_1 + T_2 - \frac{2W_2\left(\frac{h - d}{b} + \frac{z}{l}\right) - W_1\frac{k - z}{l}}{2W}D.$$

R_1 and R_2 are the pressures of the forward and rear wheels upon the rails, when T_1 and T_2 are the retarding frictions exerted upon the wheels by the rails, and D is the algebraic difference of the pulls on the forward and rear drawbars.

Now the co-efficient of $T_1 + T_2$ in each of the last two equations, is under all conditions of ordinary service a positive quantity. Therefore, the sign before each second term remains unalterable. Again the co-efficient of D is also a positive quantity and the algebraic sign of the last term is unalterable. Under certain conditions the value of the co-efficient of D in the last equation, becomes very small, but does not become negative. When D is zero the last terms disappear. The car is then free and braked to its full capacity. In this case it is evident that R_1 is larger than R_2. And the sign of co-efficient of D remaining unalterable R_1 is evidently greater than R_2. Therefore we conclude that

under any conditions when the brake shoes are applied with the same pressure to each pair of wheels, the rear pair are the most liable to slide upon the rails; and thus the maximum brake shoe pressure should be so designed that the rear pair of wheels will not slide when the brakes are applied.

Now the greatest pressure upon the rails of the forward pair of wheels which at all times and under all circumstances may be depended on for rail friction to cause continued rotation of the wheels, is when D = O.

$$R_1 = \frac{W}{4} + \frac{W_1\left(\frac{h}{b} - \frac{k}{l}\right) + 2W_2\frac{d}{b}}{W}(T_1 + T_2). \qquad (8)$$

And under the same conditions R_2 is a minimum when D is a maximum. To determine the maximum value of D, equation 7 may be transformed into the form

$$D = 2T_1 + 2T_2 - \frac{W}{g}p \ldots. \qquad (9)$$

D and p are the only variables in this equation; and D will then be a maximum when p is a minimum. We are justified in assuming that the minimum value of p is zero. Then the maximum value of D is $2\ T_1 + 2\ T_2$. This occurs when the car is pushed forward from a state of rest with the brakes fully applied. Substituting this value of D in the equation for R_2 we get the minimum pressure of the rear pair of wheels upon the rails. The brake shoe pressures must be designed for this.

$$R_2 = \frac{W}{4} - \left(\frac{h}{b} + \frac{z}{l}\right)(T_1 + T_2). \qquad (10)$$

Equations (9) and (10) are the fundamental equations for determining the proper brake shoe pressures for each pair of wheels. The rail frictions T_1 and T_2 which are obtainable to prevent skidding of the wheels are proportional to R_1 and R_2. And the maximum brake shoe pressures upon both pair of wheels are directly dependent on the values of T_1 and T_2.

Of course it is customary to apply the same pressure to the forward as to the rear pair of wheels; but our reasoning shows that a much greater pressure could be applied to the front pair of wheels with no greater danger of sliding.

Problem III.

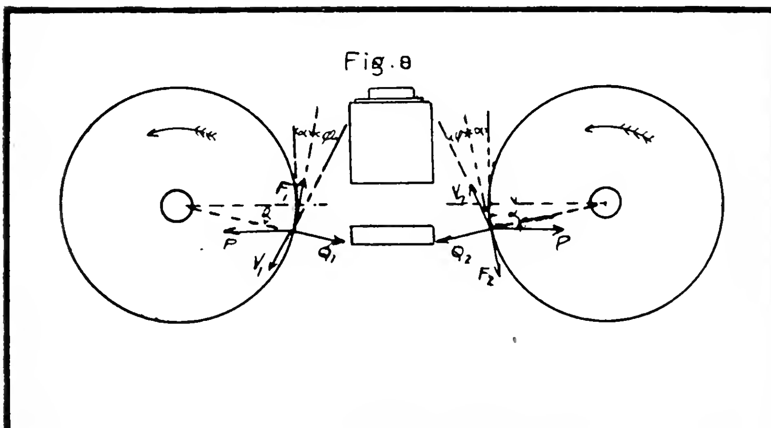
Our next problem is to find the relation between the brake shoe friction and the rail friction; or to determine the maximum safe brake shoe friction upon each pair of wheels.

Let $f_1 =$ the coefficient of static friction between the wheels and the rails.

Then $$T_1 = f_1 R_1, \text{ and } T_2 = f_1 R_2,$$

or, $$R_1 = \frac{T_1}{f_1}, \text{ and } R_2 = \frac{T_2}{f_1}.$$

Let F_1=that friction between the brake shoes and the wheels which is necessary to cause the rail resistance T_1 upon the forward pair of wheels.



F_2= that friction between the brake shoes and the wheels which is necessary to cause the rail resistance T_2 upon the rear pair of wheels.

In Fig. 8 are shown the forces that affect the relation of the forward pair of wheels. T_1 is the frictional force which causes rotation and F_1 is the frictional force resisting rotation, and is caused by the brake shoes. Let r be the radius of the wheel and ρ be the distance of any elementary mass, d M, of the wheels from the center. The retardation at the periphery of the wheels

is the same as that of the car, and the retardation at the distance ρ from the centre is $\frac{\rho}{r}p$.

The force which is exerted on the mass d M to cause a retardation at the rate $\frac{\rho}{r}p$ is d M $\frac{\rho}{r}p$. The friction F_1 must be sufficient to produce this retarding force upon each elementary mass of the pair of wheels, and also to cause the frictional resistance T_1 at the rails. Now taking the algebraic sum of the moments about the center line of the wheels, we get

$$F_1 r - T_1 r - \int dM\frac{\rho}{r}p = 0,$$

or

$$F_1 = T_1 + \frac{p}{r^2}\int dM\rho^2$$

$$= T_1 + M\frac{r_1^{\,2}}{r^2}p.$$

In the above equation r_1 is the radius of gyration of each wheel, M represents the mass of both wheels. If $w =$ the weight of each wheel, then $M = \frac{2W}{g}$. From careful calculations it has been found that the square of the radius of gyration is equal to 0.6 times the square of the radius of the wheel. Substituting these values in the above equation,

$$F_1 = T_1 + \frac{1.2w}{g}p \quad \ldots \tag{11}$$

Proceeding to consider the rear pair of wheels as we have the forward we obtain for the value.

$$F_2 = T_2 + \frac{1.2w}{g}p \quad \ldots \tag{12}$$

The value of p is given in equation (7) where

$$p = \frac{2T_1 + 2T_2 - D}{W_1 + 2W_2}g \tag{13}$$

Since we desire to find the condition which exists when the weight supported by each wheel is a minimum, we will consider the values of F_1 and F_2 when R_1 and R_2 are minimum values.

We have previously shown that when $D = O$, R_1 is a minimum, and then the value of p is

$$\frac{2T_1 + 2T_2}{W_1 + 2W_2}g \text{ or } \frac{2T_1 + 2T_2}{W}g,$$

During an emergency application of the brakes F_1 and F_2' have a fixed value, and the values of T_1 and T_2 are obtained when R_1 is a minimum, from the following equations.

$$F_1 = T_1 + \frac{2.4w}{W}(T_1 + T_2)\ ;\ F_2 = T_2 + \frac{2.4w}{W}(T_1 + T_2)$$

Solving for T_1 and T_2 we get,

$$T_1 = \frac{W + 2.4w}{W + 4.8w}F_1 - \frac{2.4w}{W + 4.8w}F_1. \qquad (14)$$

$$T_2 = \frac{W + 2.4w}{W + 4.8w}F_2 - \frac{2.4w}{W + 4.8w}F_1. \qquad (15)$$

Substituting these values for T_1 and T_2 in equation (8), bearing in mind that $R_1 = \frac{T_1}{f_1}$, equation (8) becomes

$$\frac{(W + 2.4w)F_1 - 2.4F_2}{f_1(W + 4.8w)} = \frac{W}{4} + \left\{\frac{W_1}{W}\left(\frac{h}{b} - \frac{k}{l}\right) + \frac{2W_2 d}{Wb}\right\}\frac{W(F_1 + F_2)}{W + 4.8w} \quad (16)$$

Now when R_2 is a minimum D is a maximum, and $p = o$. Therefore, under these conditions $F_1 = T_1$ and $F_2 = T_2$ obtained from equations (11) and (12). Substituting these values for T_1 and T_2 bearing in mind that $R_2 = \frac{T_2}{f_1}$ equation (9) becomes,

$$\frac{F_2}{f_1} = \frac{W}{4} - \left(\frac{h}{b} + \frac{z}{l}\right)(F_1 + F_2) \ldots. \qquad (17)$$

Combining equations (16) and (17) we get two equations from which we can obtain the values of F_1 and F_2, which will be the maximum brake shoe frictions upon the forward and rear pair of wheels, and may be used with perfect safety from wheel skidding in an emergency application of the brakes.

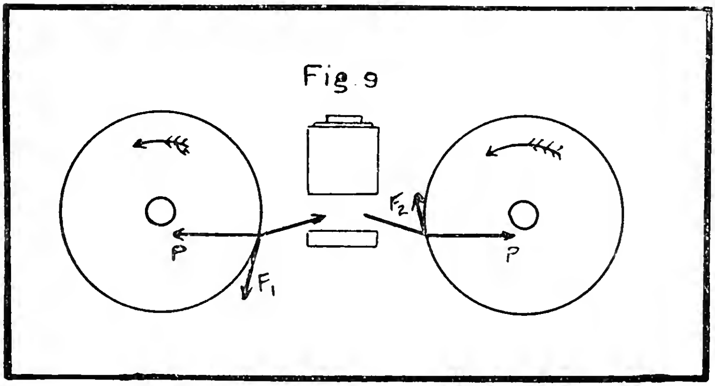
$$F_1 + F_2 = f_1\frac{W}{2} - \frac{\frac{1}{f_1}(W + 4.8w)}{W_1\left(\frac{1}{f_1} + \frac{k + z}{l}\right) + 2W_2\left(\frac{1}{f_1} + \frac{h - d}{b} + \frac{z}{l}\right) + 4.8w\left(\frac{1}{2f_1} + \frac{h}{b} + \frac{z}{l}\right)}$$

(18)

and

$$F_1 - F_2 = f_1\frac{W}{2} - \frac{W_1\left(2\frac{h}{b} - \frac{k-z}{l}\right) + 2W_2\left(\frac{h+d}{b} + \frac{z}{l}\right) + 4.8w\left(\frac{1}{2f_1} + \frac{h}{b} + \frac{z}{l}\right)}{W_1\left(\frac{1}{f_1} + \frac{k+z}{l}\right) + 2W_2\left(\frac{1}{f_1} + \frac{h-d}{b} + \frac{z}{l}\right) + 4.8w\left(\frac{1}{2f_1} + \frac{h}{b} + \frac{z}{l}\right)} \tag{19}$$

So far we have determined that, first, the rear truck supports less weight than forward truck, and the rear pair of wheels less weight than the forward pair during an application of the brakes. This led us to the conclusion that if we design our riggings for the brake pressures, the front wheels of each truck must receive the greater pressures than the rear wheels.



The following discussion will show that this inequality of brake shoe pressures may be provided for by the proper inclination of the brake hangers.

Problem IV.

Fig. 9 represents diagrammatically the action of the brakes upon each pair of wheels of a truck, when the brake hangers are in line with the tangent to the wheel at the centre of the brake shoe. The same pull P is applied to each brake beam. The brake shoes exert on the forward pair of wheels a downward frictional force F_1, and on the rear pair an upward frictional force F_2. Now with whatever force the shoes act downward on the forward pair of wheels, the wheels will react with an equal and opposite force.

Similarly the rear pair of wheels will react with an equal and opposite force to F_2. Considering the forward pair of wheels, the upward force F_1 is directly resisted by the brake hangers, which are now under compression equal to the force F_1. Similarly the rear brake hanger is subjected to a tension equal to the frictional force F_2.

Consider now an exaggerated case, in which the angularity of the brake hangers is increased, as shown in Fig. 9. Each brake beam is subject to the same pull P. When the front brake shoes have been brought into contact with the forward pair of wheels, the force which is brought into existence by the friction of the two surfaces, tends to carry the shoe upward, along the surface of the wheel. But this action is resisted, by its brake hangers, on account of their excessive angularity. Thus there is a very strong tendency to force the forward pair of wheels away from the centre of the truck. This tendency of course is resisted by the truck frame and thus a powerful pressure is exerted on the brake shoes, in addition to that pull exerted by the brake beams upon the brake shoes. In this way the brake shoe friction F_1 is materially greater in this case than that in Fig. 8, where the angle of the hanger is such that it exerts no influence to force the brake shoes against the wheels.

The effect of this angularity of the brake hanger upon the rear pair of wheels is just the reverse to that upon the forward pair. The reacting downward friction of the rear pair of wheels upon the brake shoes tends to force the brake shoes away from the wheel. This tendency diminishes the frictional force which retards the velocity of the wheels. Now if the angularity is so increased that the brake hanger would be parallel or in line with the pull P then the frictional force practically becomes zero upon the rear pair of wheels, while the mere initial contact between the brake shoes and the forward pair of wheels would almost instantly result in creating such a high frictional force F_1 that the wheels would immediately be locked and skidded.

Therefore, we must conclude from this that between these two extreme cases or limiting values of the angle of angularity it is possible to so adjust your brake shoe hangers, that the increased and diminished weights supported by the front and rear

trucks will be taken care of by the increased pressure on the forward wheels, and the diminished pressure upon the rear ones. Thus we may proportion the frictional forces F_1 and F_2 in any way desired by a proper adjustment of the angularity of the brake shoe hanger.

It will also be observed that, if in Fig. 9 the wheels rotate in the opposite direction, what has been the rear pair of wheels will now become the forward pair. At the same time the effect of the inclined hangers upon the two pairs of wheels has been reversed, so that it is still, under the reversed conditions, the leading pair of wheels which is subjected to the greater brake shoe pressure, and the rear pair which is subjected to the reduced pressure.

Thus we are enabled by this method to design brakes to meet this transfer of weight from the rear to the forward pair of wheels.

The following description of the general action of railway brakes, and the nature of the frictional forces which are brought into existence, through an application of the brakes, is to some extent, a repetition of the discussion of Problem I. When a train is moving at a given velocity the adhesion of the wheels on the rails cause them to rotate. Every point on the surface of the tire moves around at the same rate as that at which the train is moving forward. But every such point, in relation to the forward movement of the train, comes successively to rest at the moment when it comes in contact with the rail. Now when the brakes are applied with a slight pressure only, the wheel continues to move round at the same rate as the train is moving, but with more difficulty. This increased difficulty in moving is shown, either in an increase in the traction force, which is required to keep up the forward movement, or, in cases where the accelerating force is not kept up, by the tendency of the moving mass to come to rest in a shorter time. But if the pressure with which the brakes are applied be increased, a point is reached, at which the friction between the brake shoes and the wheels first approaches, then equals and finally exceeds the adhesion of the wheel to the rail. This adhesion corresponds to the static friction which exists between two surfaces at rest. The point on the circumference

of the wheel, which is in mometary contact with the rail is at rest during that instant. Thus we apply the ordinary equations for static friction to obtain this adhesive force between the wheels and the rails. Now when the friction between the brake shoes and the wheels exceeds the static friction between the wheels and the rails, the wheels first begin to revolve more slowly, and finally cease to revolve at all and slide along the rails. In this case the static friction between the wheels and the rails changes to dynamical friction, or the friction caused by one surface moving over another. The coefficient of dynamical friction is much less than the coefficient of statical friction. This has been proved by experiment. And thus the retardation in this case is much less than that in the previous one. Therefore, the most efficient and the quickest stops are made, when the friction between the brake shoes and the wheels is a little less than the friction which can be obtained between the wheels and the rails.

The friction between the brake shoes and the wheels is a variable quantity, depending on the coefficient of friction between these moving surfaces. Captain Galton in a series of exhaustive tests and trials of railway brakes during the years 1878 and 1879, succeeded in obtaining the relation between the coefficient of friction and the velocity of the train. As the velocity of the train increases the coefficient of friction decreases. This is plainly indicated in the following table, constructed from Captain Galton's experiments.

V.	Coefficient of Friction f.		V.	Coefficient of Friction.		
	Calculated.	Observed.		Calculated.	Observed.	
0	.326	.330	45	.126	.127	...
5	.277	.273	50	.118	.116	....
10	.241	.242	55	.111	.111	....
15	.213	.223	60	.105	.074	....
20	.191	.192	65	.099	....	....
25	.173	.166	70	.094	....	....
30	.158	.164	80	.085	....	....
35	.146	.142	90	.078	....	....
40	.135	.140	100	.072	....	....

These values of f can only be used, when the conditions are the same as those under which these trials were conducted, that is with cast iron shoes and steel tired wheels.

Captain Galton from a further study of his experiments, found that the point at which the rotation of the wheels is arrested, so that they slide on the rails, depends upon the amount of friction between the brake shoe and the wheel, the weight upon the wheel, and the condition of the rails which govern the adhesion between the wheels and the rails. Therefore, with the same weight upon the wheels, and the rails in a similar condition, the same amount of friction will stop the rotation of the wheels, no matter at what speed they are revolving. The relation then that the speed has to this subject is, as stated before, that as the speed increases the brake shoe pressure must also be increased to make up for the decrease in the value of the coefficient of friction and still maintain the fricton constant or a maximum.

Another feature that was brought out by these experiments. was that as the duration of time of the application of the brakes increased, the friction between the brake shoes and the wheels decreased. This the above experimenter explains as follows:—"Each surface is composed of a series of small mountains and hills and the longer the surfaces remain in contact, the quicker are these irregularities worn down, and thus the friction between these surfaces will at the same time decrease." The following table illustrates the point fully:

Dynamic Friction Cast Iron or Steel.	Velocity.		Coefficient of Friction.				
	Ft. per. Sec.	Miles per hour	At Commencement.	After 5 Secs.	After 10 Secs.	After 15 Secs.	After 20 Secs.
Just coming to rest.....	1 to 3	$\frac{2}{3}$ to 2	.250				
When moving at........	10	6.8	.242				
" "	20	13.6	.213	.193			
" "	25	17.0	.205	.157		.110	
" "	30	20.4	.182	.152	.133	.116	.099
" "	40	27.3	.171	.130	.119	.081	.072
" "	45	30.7	.163	.107	.099		
" "	55	37.5	.152	.096	083	.069	
" "	60	40.9	.144	.093	.070		
" "	70	47.7	.132	.080	.070		
" "	88	60.0	.072	.063	.058		

It is evident from consideration of Table I, that the pressure, which if applied would stop the rotation of the wheels when the

velocity is great, is much larger than that required to stop them when their velocity is small. Thus we may apply to the brake shoes at the beginning of the application of the brakes when the speed is high, an excessive pressure; and as the speed slackens gradually reduce this pressure, so that there will be no liability of the wheels ceasing to revolve before the train is brought to rest.

The force which may be exerted on the brake shoes besides being dependent on the speed of the train, is also dependent on the condition of the rail. The condition of the rail affects the coefficient of adhesion between the rail and the wheel. And since the frictional force caused by the brake shoes mu t not exceed the friction between the wheel and the rail, the brake shoe pressure, which may be used is dependent upon the coefficient of adhesion. The following table gives approx results showing the proportion that the brake pressure should bear to the weight on the wheels at different speeds and with different coefficients of adhesion for the rail and wheel contact.

Speed.		Approximate Ratio.			
Feet per hour	Miles per hour	Coef. of adhes. .30	Coef. of adhes. .25	Coef. of adhes. .20	Coef. of adhes. .15
11	7.5	1.2	1.04	0.83	0.60
22	15.0	1.41	1.18	0.94	0.70
29	20.0	1.64	1.37	1.09	0.82
44	34.0	1.83	1.53	1.22	0.92
59	40.0	2.07	1.73	1.38	1.04
73	50.0	2.48	2.07	1.65	1.24
88	60.0	4.14	3.47	2.77	2.08

The coefficient of adhesion is affected by the condition of the rails. In wet weather and with a greasy rail the coefficient is small. With a dry rail the coefficient is high. If sand is applied under each wheel when the rail is in its worst condition, the coefficient is increased to near the value it has when the rail is dry.

For passenger service 90% of the weight of the car, when empty, is the maximum brake force allowable. And for freight service 70% of the weight of the car when empty, is the maximum allowable brake force.

SIGNALING.

By R. Latham.

There is perhaps no other branch of railroad engineering that has taken such great strides within the last thirty years as signaling. Its growth has necessarily accompanied the vast increase of traffic, higher speed of trains and the multiplication of grade crossings, both highway and railroad, the latter of course being the most important. We have to look to some of those splendid systems in the United States to find perhaps the most perfect systems of signaling. The mileage of railroads on this continent is necessarily very great, hence the great expense of complete signal equipment: yet the demands of traffic have warranted in some cases, the installation of the most modern and expensive apparatus to protect the trains while running at lightning speed, and to keep them so spaced that there shall be ample distance in which they may be brought under full control and if necessary to a dead stop, in case of derailments or accidents ahead, and so avoid collision. Protected in this way we have trains running sometimes within sight of each other at speed greater than a mile a minute without the slightest danger of collision (provided the trainmen are in their proper senses), all signals being visible day and night.

The problem of grade crossings have been greatly simplified without elevation or depression of tracks. This is of great importance, especially in America where there are so many even on important roads. The clumsy and costly precaution of stopping a train at every grade crossing is now done away with by the aid of interlocking apparatus and signals, with the greatest safety and success.

The first expense of installing these interlocking plants is, of course, high, involving as they do a system of signals and derailing apparatus with the necessary mechanical connection with an interlocking tower, and there is the secondary and constant expense

of manual operation. But it has been found that even with the lightest traffic on single or double tracked roads that the sum saved annually pays a high rate of interest upon the investment.

A great deal could be written on the subject of signaling. It is not in its highest stage of development and so far its fundamental principles are not by any means numerous. Experience has taught that to space trains by time is vastly inferior to spacing them by distance, but it is a strange fact that only about fourteen per cent. of the railroads in America use the latter system, the rest using the former or some modification of it. The idea of the "space interval" system originated in England where the "time interval" system also was in use, and it was only a short time after the first trains were run under the space interval or block system that practically every English road had adopted the same system. In America the "time interval" system, which is practically a flagging system when trains become disabled, was in use as in England, but unlike the English, the "train despatcher" system was introduced as an intermediate step between the "time interval" and block systems, two systems which vary so much in their principles. It is a fact worthy of note, that wherever the block system has been introduced, it has never been abandoned, so satisfactory have been its results.

In this paper, no attempt will be made to exhaust the subject, but a sketch of English and American practice will be drawn, paying more attention to the latter, as it seems to show signs of higher development than the former, although the English still hold the record for the least number of accidents due to false signals. The fact that the English ideas of signaling are far more conservative than American, perhaps accounts for the fact that there are practically no automatic block signals in England, while in America they are becoming numerous, owing to their economy and satisfactory results. It is the intention of the writer to compare briefly the English and American practice after the principles of each have been described, so that the relative advantages and defects of each may be noted; the reader of course being at liberty to judge for himself from remarks made, which seems to him the better practice of the two.

Manual Block Signaling.

Manual block signaling is the system universally employed by English double tracked roads. The system was introduced about 1853, and subsequently parliament passed an act requiring its adoption by all important passenger lines. The consideration of such a system means a study of English practice, with its forms of signals, colors, and rules of operation.

The term "block signaling" is applied to that arrangement of outdoor signals and electric communication by which two trains may be kept spaced. In other words, the line is divided into sections or blocks whose lengths vary with the necessities of traffic. Lines with heavy traffic or great frequency of trains, have blocks a mile in length and sometimes less; those which run trains less frequently, have sections as long as five miles. Only one train is permitted to be in a block at a time and permission to enter a succeeding block is given by an attendant situated in a signal tower at the beginning of that block. The attendant at each block cabin keeps watch of the trains passing him, records the time of their arrival and informs the attendant at either side of him. He sends to the signal tower in advance a warning that a train is approaching and to the tower in the rear the assurance that same train has arrived and passed his cabin, thus authorizing the latter to set his signals for a second train.

The English block system has remained practically unchanged for the last quarter of a century. The invention of new mechanical "locking" devices has wrought some slight changes, but the methods have remained the same. A series of signal cabins or towers placed at different distances (according to the length of the block), keep the trains so spaced that only one train can be in a block at once (except when "permissive" blocking is done). These cabins are so located that they can operate switches and cross-overs from main lines. Near important towns and junctions they are often placed within sight of each other, as the distance from switches must not exceed about 540 feet in the case of split switches, and 900 feet in the case of throw switches, in order that they may be workable. When once a train has been despatched from a town its running is left entirely to the cabin operators, so that

safe handling depends entirely upon the watchfulness and obedience to rules on the part of the operators themselves. The operation of one signalman is contingent upon that of another owing to the use of electric locking apparatus between two succeeding cabins, and by having electrical communication, both may act in conjunction.

When operator at A wishes to send a train into the block section A-B by push button and bell signal, he registers "be ready" on an indicator instrument with which each cabin is supplied, and then it is repeated back to A, whereupon the operator at A gives a description of train by bell signal, and if B is ready to accept train, he puts the handle of his instrument in the position meaning that he accepts train. This causes indicator at A to go to "line clear," whereupon A can set his signals at "safety," after which he gives a dial signal to B, showing train on line, which B acknowledges. Such messages require only a few seconds for transmission, so that the fastest flyer may proceed from block to block finding signals set at "safety" for each block, although normally at danger. When the blocks are short and trains frequent it will sometimes keep the signalmen on the alert, to have their signals properly set, and in this case the operators are permitted to give the warning "be ready" in advance, so that the signals may be "pulled off" considerably in advance of passing trains.

Sometimes more than one train is permitted into a block at one time. This is called "permissive" blocking, and is only practiced on busy freight tracks, on block sections in large cities. The operator A records the number of trains he has allowed into the block, and operator B recording when each train leaves the block, keeps operator A posted as to how many trains are left in the block.

Form of Signals.

Practically the only form of signal in use on the important lines of England, are of the semaphore type. For main line switches a ground disc signal is used. The almost exclusive use of the semaphore type is the result of a joint agreement of the roads. The Board of Trade, which has power from parliament

to control in some respects the railroads of Great Britain, has recommended the universal employment of the semaphore type and it has therefore become the standard signal for practically all lines.

The English semaphore differs little from others; the blade or arm is about 6 feet long and 9 inches wide throughout there being no taper to the arm, unlike the American. The blades of home signals have square ends, those of distant signals have fish-tail ends. Those for low speed or freight tracks are distinguished from those for high speed tracks by a white circular ring on the face and a black one on the back. The horizontal position of the arm is taken to mean "danger" or "stop," while the inclined position (at 45° or 60° with the horizon) "safety" or "proceed." When there is nothing on line these are set at danger or in the horizontal position, or, in other words, the "normal" position of the semaphore is always at "danger." This seems to be a rule of English railroad signaling that is observed on every road. The block signals are interlocked with main line switches nearby, the signal cabins being so placed as to serve the purpose of interlocking towers for the switches.

Color of Signals.

The blades of the home and distant signals are painted alike, red on face with a white band across it, and white on back with a black band across it. Nearly all important roads have adopted green for safety and red for danger for night signals. Originally, white was the standard color for safety, which is still the case on the majority of roads in America. To change from one color to another means a great expense to a railroad, so it would have to be almost a case of compulsion before such a step would be taken. The fact that in such a densely populated country as England an observer at night would see nothing else but white lights is the reason for such a change. It was found that a distinctive color for safety was required so that the engineer would not mistake the light on some bridge, or in a house, for his safety signal. This is perhaps the strongest objection raised to the use of white light for safety, and it has had such weight with managements of the various roads, that in spite of the great expense in-

volved, they have one and all abandoned the white and adopted the green light for safety.

A second reason for the change from white to green, lies in the fact, that it was the custom of some roads to have their semaphores show a green light (meaning caution) in large stations and busy yards, as the running of trains through these parts had to be done with the greatest caution. The arm would be set at "safety" while the light indicated "caution." In the country the arm would be set at safety while the light indicated "proceed." This inconsistency led to the belief that a signal meaning caution should be discarded as unsafe, and that there should be but two signals, "stop" and "proceed," and if caution in running through certain districts be required, let it be expressed by order board or written order.

Placing of Signals.

The position of signals, so that they may be viewed with ease, is a problem not always easy to solve. The shape of the road, the presence of cuts or bluffs, will present difficulties in placing signals. In England, railroads run exclusively on the left hand tracks, and this practice is carried on to some extent in America. In most cases the signal posts are placed to the left of the track they govern, the arm pointing away from it. This is the rule, but it often happens on curves that the signal post governing the left hand track is placed on the right of the railway line, making the situation rather complicated to the observer, but to the engine driver who knows every foot of his road, perhaps this is of little consequence. He of course can remember the rule that all signals governing his train have the blades pointing to the left from the post. This rule,of course, is of use to him only during the day when the blades are visible, but at night he has to be on his guard and know the peculiarities in the placing of signals.

Sighting of Signals.

The "sighting" of signals, *i.e.*, the placing high or low that they are visible to the engine driver, is done with the greatest care so as to get the best possible height for clear vision. Posts as high as

fifty feet are required for this purpose, and even then it is sometimes necessary to build a back ground for signals in order to make them visible day and night. On four track lines and near junctions and terminals, where there are numerous parallel tracks, signal bridges spanning the tracks are constructed high enough to give ample head room for brakesmen. These structures are built light, usually of iron, and afford the best means of placing signals as each track can have its governing signal directly over it. Instead of these bridges a cheaper stand for signals is found in bracketed posts, a signal being placed on each bracket. This means of placing signals is getting away from the simple and natural way of having each signal directly over the track it is intended to govern, and then there can be no mistake in the interpretation of the signals.

Distant and Home Signals.

In English block signaling there is really no difference between the home and distant signal as far as the position of the blades and color of lights are concerned. The distant signal has the fish-tail end while the home has the square end. At night, however, only the lights are supposed to be seen, and red and green are used for "danger" and "safety" on both home and distant signals. If an engine driver finds his distant signal at danger he knows that he may expect to find the home at the same, and slackens speed so that, if necessary, he may come to a full stop without passing the home signal. The distant signal then is simply a forewarning to the engine driver as to how he may expect to find the home signal.

The home signals mark the end or the beginning of the block and are therefore placed opposite the signal towers. The distant signals are placed from 2,000 to 2,500 feet in the rear of the home signals, giving sufficient distance for the speediest and heaviest trains to stop before passing the home signal. When permissive blocking is done the train is required to come to a full stop at the home signal and is then allowed to proceed on verbal order from the towerman. When the blocks are short (about ½ mile) the distant signal of a block is often placed on the home

signal post of the block in its rear. This is found convenient and economical. The fact that a distant signal might not be visible owing to the lamp being out or burning dimly is provided for by means of an apparatus which rings a bell in the cabin. In foggy weather, torpedoes are placed on the track opposite the distant signals as a warning to the engine driver that he is approaching the home signal.

American Block Signaling.

The manual blocking just described is practically the only system of signaling in use on English railroads, and it has been found to be the only practicable one suited to English traffic which necessarily is very heavy. In America different conditions prevail. The railroads here have a great mileage, many lines have only one track, some two, three and four tracks. Some of these run through country sparsely populated as well as through thickly populated districts, so that we often find more than one system of signaling on the same road, the system being more complete in the thickly populated districts than in the open country.

Telegraph Blocking.

The simplest form of block signaling in America is the telegraph block system. This resembles very much the English manual blocking, but has not the same degree of interlocking of switches and signals as the latter. It is used only on lines of great traffic between important cities where trains run very frequently. It is fast being superseded by the automatic system as the expense of operating involved in salaries of operators, maintenance of apparatus and structures is great compared to the latter.

The track is divided into blocks or sections varying in length from one to four miles. Signal cabins are placed at the beginning of each block. The signals operated from these cabins authorize trains to enter the various blocks. Figure 1 represents a block section with the home signals a & b. A train in passing in the direction A B is permitted to enter the block by the lowering of semaphore arm of signal a, operated by the attendant at cabin A. If arm of signal a is in the horizontal position, the engine driver knows that block is not clear and awaits until it

is lowered, when he may proceed as far as signal b, where he gets permission to enter the next block B-C. After train has passed cabin A, it is the duty of the attendant at A to bring his signals to danger—the normal position of all home signals. After train has passed B, he notifies A, so that he (A) may lower his signals for another train.

Signals.

The signals are of the semaphore type, with the arm so arranged as to give three positions. The arms are from five to six feet in length and taper towards the point of suspension. The home signals are painted yellow or red on the face with a band near the end, and white on the back. The distant are painted green on the face with white on the back. They are mounted

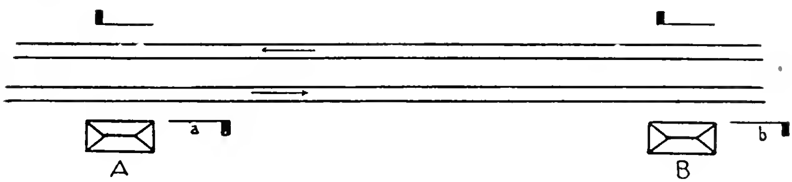


Fig. 1

on wooden posts usually from 20 to 30 feet high, set on the right hand of the track they govern with the blade swinging to the right of the post. A counterweight causes blade to assume the horizontal position should the wire connection between the cabin and the signal post break. Distant signals are used as an indication of the position of the home signals, being fitted with white and green lights, the home signals showing three lights—red, green, and white. They are placed from 800 to 2,500 feet from the home signals, the levers operating each are interlocked so that distant signals cannot be thrown to safety until the home has assumed the same position; and therefore a home signal can be thrown to the danger position the distant must be thrown to "caution." Where blocks are short it is found economical to place the distant signal of a block on the home signal post of the block in the rear.

Figure 2 is a sketch of the three position semaphore; the semaphore casting is so constructed as to carry red and green lenses. The position (a) means danger, (b) caution, (c) proceed. Positions (b) and (c) are the only ones assumed by the distant signal. Where blocks are long, it is often desired to do "permissive blocking," or allow more than one train in a block at once. The home signal is made to assume the position as shown in (b), which means that the train may proceed with caution, or else the signalman may leave his home signal at danger, and use a green flag (by day) or light (by night) to allow a second train into the block.

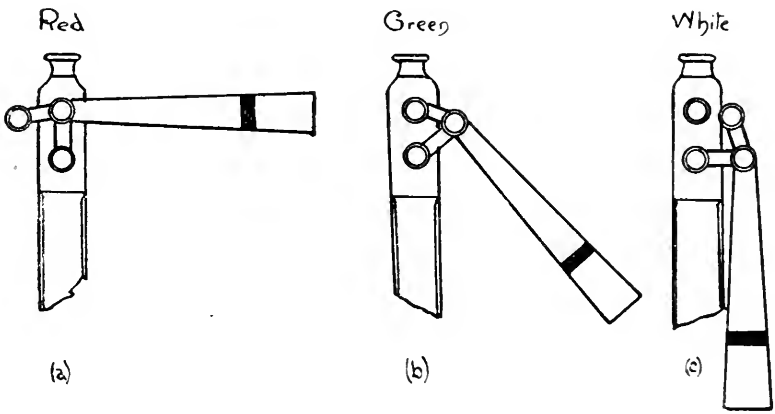


Fig 2

Single Track Blocking.

Not only has the simple telegraph block system been in use on lines of two tracks or more, but also on lines of single track. The success with which such a system has met seems to have led largely to its adoption on single track roads. A system of signaling that will give full protection to trains as well as quick handling on lines of two, three or four tracks will give the same results on single track lines. This system has proved a success even when stations are twenty miles apart, provided there is not too great a frequency of trains. With trains running every hour

and stations not exceeding thirty miles apart, this system has been used advantageously, the station agents under the direction of the train despatcher, performing the duties of signalmen. The train despatcher arranges the spacing and crossing of trains. Orders are received by the station agents who must operate their signals accordingly. A train having reached a certain station, has semaphore set at "clear," so that it may proceed. This does not indicate that the block ahead is clear, but merely that so far as is known by the agent at that station, it may proceed. But the engineman having received duplicate orders from the train despatcher can proceed to the next station or side track where they meet and cross an opposite train to which similar orders have been given.

The signalman at each block station is required to keep his block signals set normally at "danger," except during hours when his particular signals are authorized to be closed. The closing of signals is only done when there is a scarcity of trains. Blocks are thus made larger, so that through freights and passenger trains may be allowed to pass stations without slackening speed.

Forms of Signals.

There are different forms of signals in use in single track blocking, some roads having designed special semaphores. Those described in the double track blocking are the commonest. Three phase semaphores with the horizontal and two inclined positions of the arm, one being above the horizontal are in use. The latter position is used when it is desired to do permissive blocking (only done of course with trains running in the same direction). The latter then is a cautionary signal and means proceed with caution. The arm is inclined at 60° to the horizontal in both the caution and clear positions.

Position of Signals.

Each set of signals (home and distant) is placed to the right of the track so trains will always find governing signals to the right. The arms are swung to the right. Distant signals are placed from 800 to 2,500 feet from home, according as the grades and curves run in the vicinity of the block station. The home

signals are often placed on the block station itself, having only one home for both directions and operated from inside. The distant signals are operated solely by hand power, having pipe and wire connections from a lever to the signal post.

The Controlled Manual Blocking.

The controlled manual blocking used in American practice, is almost identical with English manual blocking. It is so called because the operations of a signalman at one end of a block are contingent upon those of the signalman at the other end. This is made possible by the use of electrical apparatus invented by "Sykes," an English engineer. Briefly, the apparatus consists of a series of electro magnets so connected with the levers operating the signals at one end of the block (call it A), that the levers operating signals at the other end of the block (call it B) control those at A. In order that a train may be admitted into a block A-B, the permission of both A and B is required. For example, when A sends a train to B he at once places his signal at danger, and it is impossible for him (A) to release that signal until B unlocks it, and B cannot do that until train has cleared the section. In case B should, by mistake, try to unlock A's lever before train had cleared the section, an automatic arrangement is provided so that A after having admitted train and placed his signal at stop, cannot unlock his signal to "clear" until train itself has actually passed out of the section. This is done by running an electric circuit controlling A's lever, through two or three rail lengths of track just beyond B. The current goes from the battery to one rail of the insulated section of track, thence by wire to A's signal, which it holds "locked" at "stop" by energizing an electro-magnet. When train passes over the insulated rails most of the current passes through the wheels and axles from one rail to the other, and thence back to the battery without going to the electro-magnet at A. This demagnetizes that instrument so that signal may be cleared for next train.

The automatic arrangement becomes useless if permissive blocking is done. There being two trains in the section, the first

one will release A's lever while there is a second train in the section, thus allowing a careless operator to clear his signals for a third train.

The form and color of signals are similar to those used in telegraph blocking.

A full technical description of the controlled manual apparatus may be found in the Railroad Gazette of August 24, 1900.

Automatic Block Signaling.

The manual system of block signaling is the most expensive of all, owing to the cost of operating. In America where the mileage of railroads far exceeds that of English, it is not surprising to find it adopted by comparatively few of the roads that favor the block system. It is only in use over small sections of line running through a populated country between important towns. The manual system here referred to is that where the blocks are made short, and stations for sole object of signaling are built at the beginning of each block. The employment of an attendant night and day at every station is an expense which few American roads could bear, and the first expense in establishing these stations for the sole purpose of signaling would sink many roads into ruin. Even the lines that have adopted the manual system, owing to the enormous expense have been deterred from placing the block signals as near together as they ought to be for convenient working. In consequence of the excessive lengths of the blocks they have introduced the permissive system, virtually suspending for the time the safeguards of the block system. This seems to be equivalent to throwing away a portion of the money spent for the erection and maintenance of plant.

As the result of the enormous expense attached to the manual operation of block signals, various automatic devices have been invented to eliminate the employment of human attendants. These depend upon the aid of electricity and compressed air, although elaborated systems have been devised from which electricity was eliminated altogether. American signaling authorities claim that automatic devices to replace the manual operation of signals, afford the most perfect and economical means of spacing and handling trains. The automatic system is the outcome

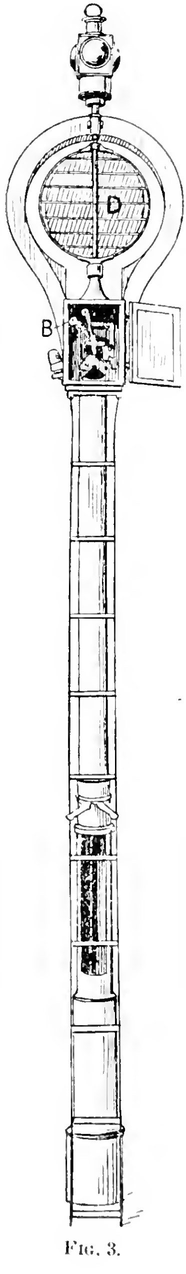


FIG. 3.

of necessity arising from a great mileage with increasing traffic, with a financial inability to employ human attendants.

The earlier forms of automatic signals depended, for communication between blocks, upon wires strung on poles. Electrical apparatus was used to hold a signal at the beginning of a block at "danger" until train had cleared that block. Owing to fact that a train might break in two, leaving one portion of it in a section while the other had cleared, the track circuit system was adopted.

Track Circuit System.

In this system the current is conducted by the rails of the track and so long as that current remains uninterrupted the signal is held at safety by an electro-magnet. A train entering the section makes a metallic connection between right and left rails. The current being interrupted causes signal to change from safety to danger.

Signals.

Figure 3 represents a form of disc signal used commonly in automatic signaling. It is mounted upon a hollow iron post about sixteen feet high. It consists of a disc or target D, which is fixed to a vertical spindle on the top of which the lantern stands. The latter has red and white (or green if white is not used for safety) lenses on opposite sides. The spindle is connected with clockwork (in box B) operated by a weight which hangs down the centre of the post. The weight has to be wound up at regular intervals.

The disc D is painted red on both sides, and when set with its face towards the engineman means "stop," when turned with its edge towards the train means all clear. Sometimes a second disc fixed to the spindle and at right angles to the red disc is used. This is painted white (or green if white is not used) on both sides and indicates "all clear."

The clockwork is governed by an electro-magnet. As the current ceases the clockwork is allowed to move until the spindle has been turned through a quarter of a revolution. In case the clockwork should be run down completely and by chance leave the signal at "all clear," the current is made to pass through a pair of springs which are held together when the weight is wound up, but which are separated when the weight has nearly reached the bottom; so that just before the clockwork is run completely down the current is opened and signal left standing at "stop."

Positions of Signals.

Home signals are usually placed directly at the beginning of the block they protect, and to the right of the track they govern if it is the rule for trains to run on the right hand track. In order that the enginemen may know that signals are working properly, a block signal standing at "all clear" is made to change to "danger" when the train is within 200 feet of the block. The objection sometimes raised to this, is that a misplaced switch might cause the signal to move to danger just as the train was entering the section, and the engineer would naturally suppose that his train was the cause of it. On the other hand, where signal changes to "danger" after train has entered section, there is no check upon the working of the signals. To station brakemen, on the rear end of trains, to observe the working of signals is attended with too much difficulty to be practicable. But in any case where automatic signals are used, there should be no doubt as to their efficiency, as experience has proven that care and close inspection of apparatus warrant the assumption that dangerous failures—the greatest of which is failure to go to "stop" when train enters a section—will not occur.

Arrangements of Signals.

Figure 4 represents an arrangement of automatic disc signals. In this system the signal stands "normally" at danger until a train enters the block in the rear, and then if everything is clear in the block, it assumes the clear position, which it retains until the first pair of wheels passes the block insulation shown -[ ]- when it assumes the "danger" position. Train A having passed D, H, and D_2 holds them at danger, but since the clearing section of H_2 has been entered the signal H_2 stands at safety.

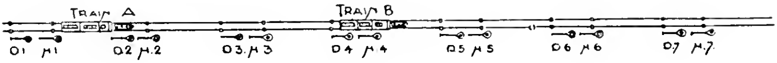


Fig.-4

Train B has entered the clearing section of D_5 and H_5, but a broken rail shown -( )- in advance holds them at danger, for which reason train B will stop upon reaching H_5 and then proceed with care until it reaches D_6 and H_6, which are in the clear position. D_7 and H_7 naturally stand at danger, since no train has entered the clearing section in their rear.

Overlaps.

Instead of providing distant signals the overlap is employed. By an overlap is meant one block section overlapping another. The overlap is about 2,000 feet long and is only used when the "normal danger" arrangement of signals is employed.

Fig.-5

Figure 5 represents an arrangement of signals where there are no distant signals, the overlap being used instead. A signal occupies the danger position until a train enters the block in its rear, and then if everything is safe on the block and overlap in advance it assumes the clear position, which it retains until the first pair of wheels passes the block insulation shown -[ ]- near the foot of the signal post, when it resumes the danger position

and holds it under all circumstances until the last pair of wheels has passed the overlap insulation, shown -||- beyond the next signal in advance. The signal may then be cleared by an approaching train as in the first instance, but will otherwise remain at danger. Train A having passed S, holds it at danger, but as it has entered the clearing section of S_2 and nothing intervenes in advance, S_2 is found in the clear position. Train B having passed into the block of S_4 holds it as well as S_3 whose block it has not entirely left, at danger. Under ordinary circumstances S_5 should be in the clear position, since there is no train in advance of it, but in this case there is a broken rail, shown -( )- which holds S_5 at danger. For the same reason S_6 is in the clear position, for in this arrangement of circuits, it is the interruption of the circuit in the block immediately in the rear of the signal which tends to clear that signal. This feature, which at first glance seems singular, is consistent, since it is the danger in *advance* of a signal which it is supposed to indicate. Train B will pause upon reaching S_5 and after waiting a certain number of minutes will proceed with care through the block section until it reaches S_6, when its course will be clear.

Wire Circuit System of Automatic Block Signals.

Those who favor the wire circuit system claim that the track circuit is not so scientific as the former, and that a broken rail, although serious enough to cause derailment, does not affect circuit sufficiently to cause a danger signal. The wire circuit system operating *enclosed* disc signals is perhaps the most efficient and reliable, owing to the simplicity of its apparatus and to the fact that the current is conducted by wire.

Form of Signals.

Figure 6 is a cut of the signal itself. It consists of a hollow case of metal or wood with a white glass aperture, and painted black, which forms a contrasting color to white (safety) or red (danger), thus forcibly attracting the attention of the engineer. Figure 7 represents the interior of the case. It contains an electro-magnet which, on being energized, holds a red disc (made of silk

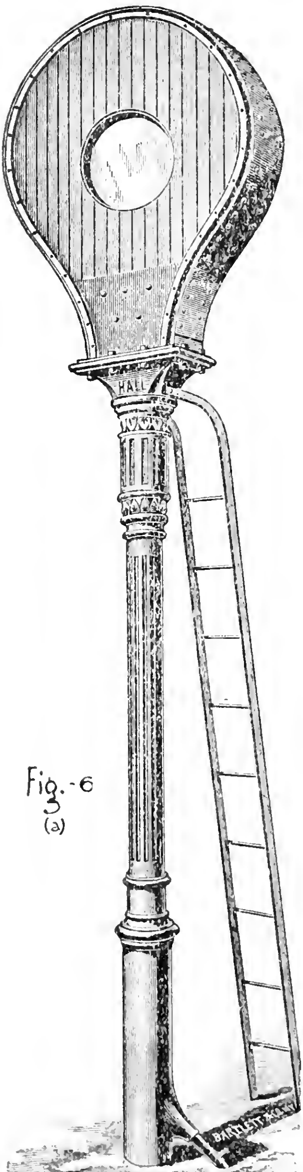


Fig.-6 3 (a)

"LINE CLEAR"

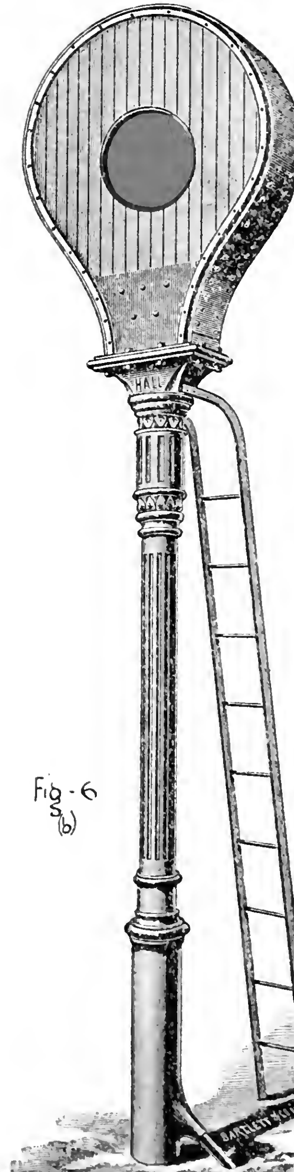
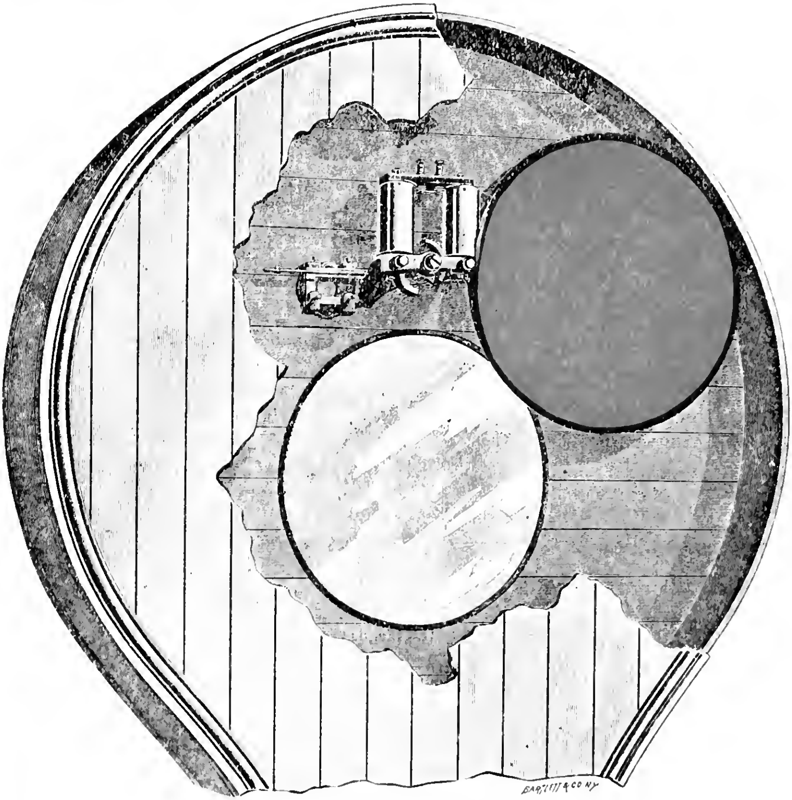


Fig.-6 3 (b)

LINE BLOCKED"

stretched on an aluminum ring) up, which otherwise would fall down owing to gravity and cover the glass aperture making the danger signal. A white reflector is shown through the aperture when the red disc is drawn up, making the safety signal. The position of the lamp is shown in Fig. 6. During the day it is hung below the glass.



INTERIOR VIEW OF SIGNAL CASE.

"SAFETY."

POSITION OF SIGNAL (BY ELECTRO-MAGNETISM)

Fig. 7

Distant Signals.

The distant signals are practically the same as the home, only the discs are green instead of red. They are included in the cir-

cuit, and therefore act in conjunction with the home; that is, a green distant signal indicates that the home will, or is likely to be, red. A white distant signal corresponds to a white home signal. They are placed about 1,000 feet in advance of the home signal. By a judicious arrangement of these distant or cautionary signals, no home signal need ever be made visible beyond a few hundred feet.

The prominent feature of the enclosed disc signal is that the moving parts are protected from wind and rain and snow, and therefore can be made light enough to be moved by an electro magnet of moderate size.

The principle upon which this signal is operated and constructed is that the first wheel entering a block section sets the signal at danger, and at the same time breaks an electric circuit in such a way that under no possible contingency can the signal again show safety until the train passes out of the block section and operates a track instrument which restores the circuit. If a wire breaks or is grounded, or two wires become crossed, the signal falls to danger by gravity. The failure of the battery or derangement of parts always brings signal to danger. In other words the safety position of the signal is dependent upon an uninterrupted circuit through the magnets of the signal instrument in the case. It is simply the attractive power of electro magnetism that holds the signal at safety. The movement of signal to danger position is not dependent upon the action of force such as the unfastening of a mechanical lock or opening of a valve, but simply by the action of gravity on the interruption of the electric current from a lack of force to hold it in the safety position. The safety position therefore is only assumed when all the apparatus is in perfect order and no train has entered the section.

Track Instruments.

Track instruments are used to break and make the circuit, being operated by the wheels of passing trains. Two are required for each (simple) block. The first, called the "block" instrument, is located at the beginning of the section, and is constructed as to break the circuit (when operated by train) so that the home and distant signals fall to danger and caution respectively. The

second, called the "clear" instrument, is placed about 2,000 feet beyond the beginning of the succeeding section, so that when the first pair of wheels of the longest train has operated that instrument (thus closing the circuit), the whole of the train will be out of the first section.

"Clear" Track Instrument.

Figure 8 represents sectional view of the clear track instrument for closing the circuit. L is a lever or treadle operated by a passing train. The lever being depressed at track end, forces

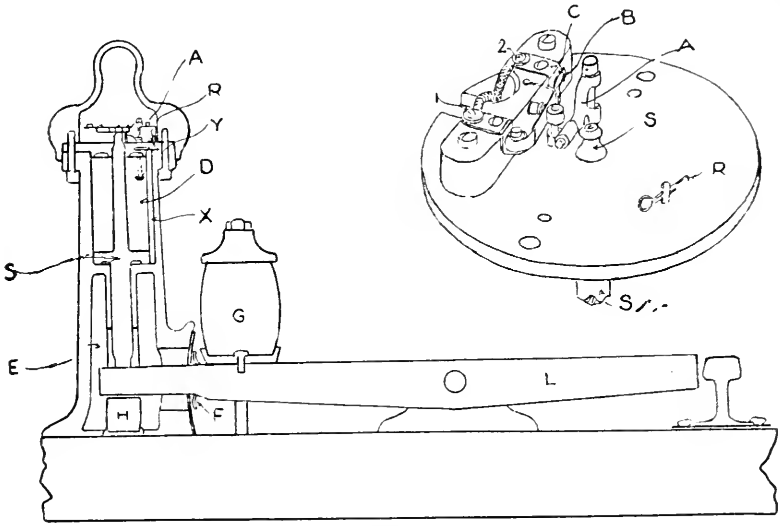


Fig.-8

the piston S moving in an air chamber D, and communicates motion to the key lever A of the circuit closing apparatus. The upper and lower ends of the air chamber are connected by a post X, so arranged that when the piston is forced upwards a portion of the air above the piston is forced out through the opening Y. When the piston has risen high enough to cover the opening Y, communication with the lower end of the cylinder is cut off and the air remaining in the upper chamber forms a cushion, preventing the piston from being thrown forcibly

against the top cap. Upon being actuated by the lever L its bevel top engages a roller on the arm A, which forces the spring B to a contact with its anvil C, thus completing a circuit between the wire connections of 1 and 2.

The piston having been raised by a passing train the air above it is driven through the port X and enters the air chamber below the piston, thus forming a cushion preventing serious shocks. R is a valve for regulating air pressure, The lower end of piston rod moves in closed chamber E. Movable plates F attached to the levers keep this opening closed. H and G are two compresser rubber springs, so that hand cars, velocipedes or any weight less than an ordinary car wheel will not operate the piston.

The track instrument just described is used to close the circuit, being so placed as to allow the longest train to have cleared a section before the signal protecting that section assumes the clear position. The "block" instrument is alike in principle and construction to the "clear" track instrument, except that in the case of the former, the current is broken when lever is actuated by the wheels of a passing train.

Block Signal Circuits.

Figure 9 shows the arrangement of battery wires and instruments for operating a simple circuit. D is block instrument (heretofore described), placed at the beginning of the block section. B is the clear track instrument situated at the other end of circuit, or about 2,000 feet beyond the beginning of the next block. R is a relay and X the battery, both of which are located anywhere within the block. In Fig. 9 (^{a}) the circuit is closed and signal is held at safety, the circuit being from battery X wire 1, anvil E, spring D, wire 2, electro-magnet S, wire 3, contact points p, p^1 of relay R, wire 4, electro-magnet r, wire 5, to battery. The first wheel of a train entering a section operates the block track instrument breaking the circuit between spring D and anvil E, demagnetizing electro-magnets r and s. Signal falls to danger and contact points p and p^1 are broken. When train has completely cleared the block track instrument D, contact between spring D and anvil E is restored, but as circuit is still broken at points p, p^1, the signal will remain at danger until

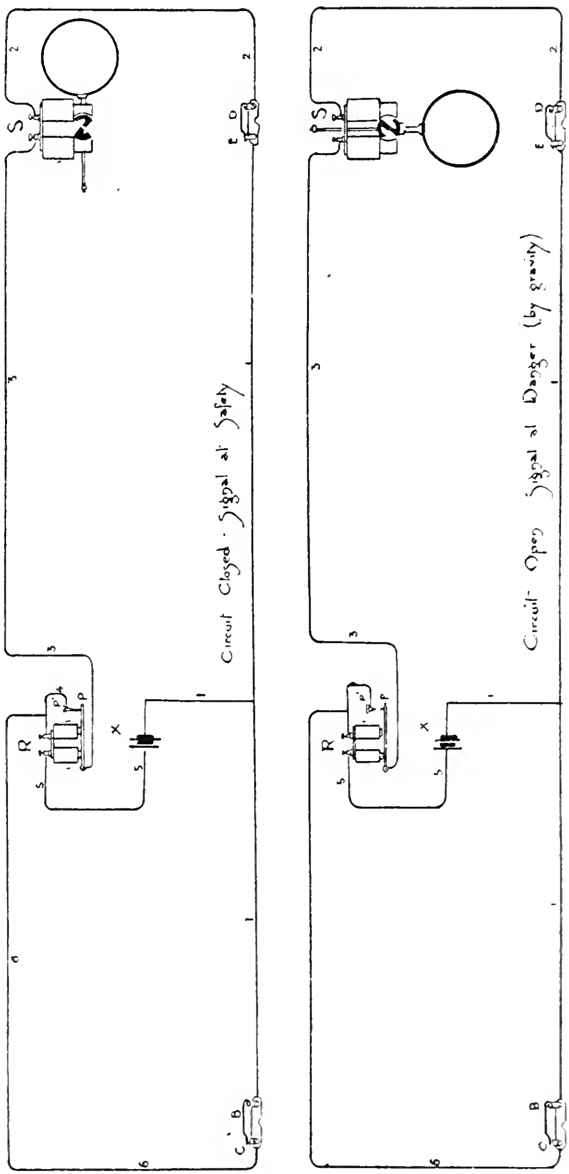

Circuit Closed · Signal at Safety
Circuit Open Signal at Danger (by gravity)

Fig - 9

train operates clear track instrument B, which energizes electro-magnet r, thus completing circuit from battery X, wire 1, spring B, anvil C, wire 6, electro-magnet r, wire 5, to battery. This closes contact points p, p[1], but the signal still remains at danger until train has wholly cleared the clear track instrument, on account of the fact of there being two circuits, one through the clear track instrument and relay magnet and another through block track instrument, signal magnet and relay magnet. As the resistance of the latter is much greater than that of the former, the signal will remain at danger as long as clear track instrument spring is in contact with its anvil, which under action of air cushion previously referred to is continuous during passage of train at ordinary speed.

Switches in Signal Circuits.

Any number of switches may be included in a circuit. A misplaced switch, that is a switch set for a siding, causes a break in circuit by operating a switch instrument similar to the track instrument. This causes signal to fall to danger, and as long as the switch is misplaced the signal cannot be cleared.

Single Track Blocking with Disc Signals.

The use of automatic disc signals as described, is calculated for two tracks where trains run always in the same direction on the same track. They may be used equally well, however, for single track blocking. The block sections are arranged to extend from side track to side track. The signals are controlled by electric interlocking and they may be arranged to automatically give the right of way to one train or another but not to both. It is impossible, however, for any mechanical contrivance to choose between a passenger and freight, or between an east bound fast stock train and a west bound train of empty cars.

As automatic signals are confined usually to lines of more than one track where traffic is heavy, their application to single track lines will not be discussed, as most single track lines space their trains by the time interval system, or a system of station blocking.

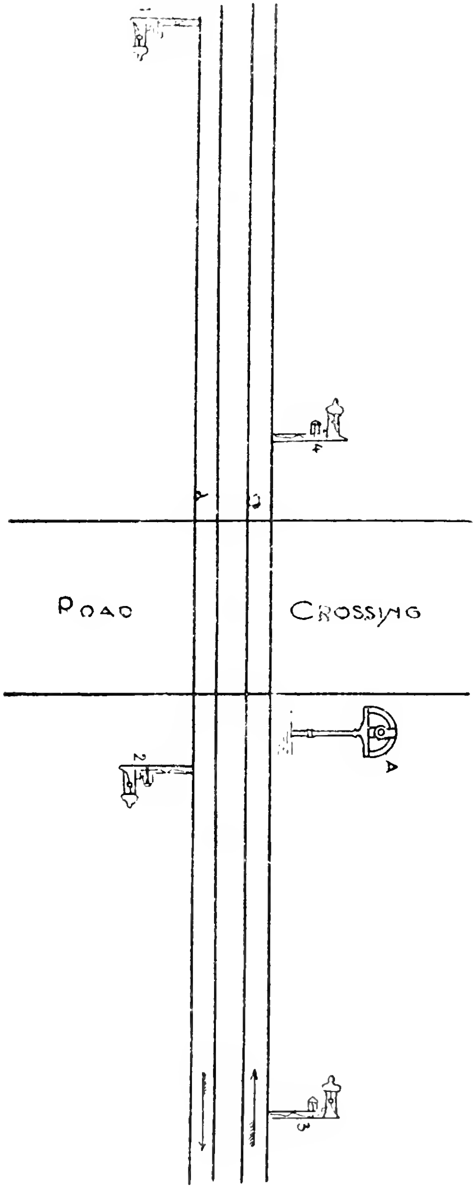


Fig. 10

Audible Highway Crossing Signals.

The track instruments described in connection with the wire circuit system of automatic signals may be used advantageously to give audible warning to pedestrians of passing trains at road crossings. Figure 10 is a plan of signal and track instruments used in connection with a double track. The wire conducting an electric current by means of which an approaching train sets the bell ringing is run to the track instrument, located at any desired distance from the crossing. The circuit is normally open. A west bound train in passing over track instrument 3 closes a circuit and energizes an electro magnet A in an interlocking instrument located together with the battery at the crossing. This closes a local circuit through spring D and its anvil d and starts the bell ringing. The instrument now being locked, the bell continues ringing until train shall have reached instrument 4, which closes a circuit energizing unlocking magnet B, which breaks the contact between spring D and its anvil d, thus opening the bell circuit and silencing the bell.

By an arrangement of interlocking instruments and track instruments the bell may be made to ring by a train approaching from either direction on a single track.

The Electric Semaphore.

The electric semaphore signal to be used in automatic blocking, is the latest development. The claim has been made that disc signals are less distinctive to the eye than semaphores, but this is a matter of dispute. This fact led to many experiments with electrical apparatus to operate a semaphore arm of full size, apparently with success although no extensive installations have been made. The prominent feature of this style of signal is that each has its own independent motive force. An electric motor of about ⅙ H.P. placed in a box attached to the post below the arm, and supplied with current from an Edison-Lalande battery of 10-16 cells, winds a cable on a drum, thereby lifting a counterweight (which holds the signal arm normally at danger), giving the arm the inclined or all clear position. With such a powerful force exerted by motor, and use of a heavy counterweight, difficulties of snow and sleet causing arm to stick is overcome. The

motor has an automatic brake, consisting of a resistance coil, which retards the revolutions of a soft iron circular disc fixed to the armature shaft.

The semaphore blades are same in design as the standard: ball bearings are introduced to eliminate friction. Bells are provided at main line switches, which may only be opened when bells are not ringing. A train in a section to the rear of the one in which a switch is located causes the bell to ring. On the other hand when the switch is opened the signal at entrance to the block is drawn to danger. The signals are operated by track circuits.

Electro-pneumatic Block Signals.

This style of signal has been in use since 1885. They are only used on the busiest portions of lines, usually four track roads, where the sections are short. The power is supplied by compressed air, which flows through valves operated by an electric current. Air compressing plants are established where possible in yards, where they serve the purpose of supplying air for electro-pneumatic systems of interlocking switches, and air for several miles of blocking outside the yard.

The essential parts of the system are:—

(1) The electrical apparatus, consisting of the battery, track relay and connections, and electro-magnet for controlling admission of air to cylinder.

(2) The signal, which is a full-sized semaphore.

(3) A cylinder with piston for moving signal.

(4) An air compressor plant with reservoirs and cooling pipes to precipitate any excess of moisture, and a pipe to convey air under pressure to signals.

The block sections being very short it is found economical and convenient to place two signals on one post, one being the home signal of a section and the other the distant signal of the following section. The former is placed at the top and is of the standard form with a square end. The latter is placed below and has a fish-tail end to distinguish it from the home signal.

On roads of more than two tracks it is usual to define the blocks by signal bridges spanning the tracks, each pair of signals being placed over the track they govern.

This system of automatic blocking is necessarily very costly, owing to the great expense of operating compressor plant, laying of pipe, pneumatic cylinders and electrical apparatus, and this has consequently limited its use to roads where *one* line of pipe will operate the signals of several tracks.

Manual versus Automatic Signaling.

The opinion as to the relative efficiency of manual and automatic systems is divided, even in America. The controlled manual, about which there is a certain amount of automatism on account of the electrical apparatus which makes the setting of signals at the beginning of a block contingent upon that at the end, is operated by human attendants who are not infallible, and liable to error, the result of which may be serious, or slight, or even of no consequence. The element of contingency between the operators eliminates to a great extent any errors made by one. Methods are known to expert operators of "cheating" the machines, by which mistakes may be rectified.

The efficiency of the manual system depends to a great extent upon the operators themselves, some of whom may show a tendency to getting "out of order" themselves once in a while, when duties are light, or, in other words, when the frequency of trains is small, the operator may fall asleep, and although no very serious results may happen, his neglect of duty may cause delay, something which every railroad tries to avoid. Cases have been known where the operator would deliberately prepare for a nap, by getting an unlock from the towermen on each side of him so that he could clear his signals; in which case train must stop at tower in the rear and procure a caution card and then proceed under full control to the tower of the "sleeping beauty."

Such cases could not properly be cited as dangers of the system, but merely defects which may be remedied by the employment of reliable operators. In England, where the controlled manual is practically the only system in use, the record of train

accidents due to misplaced signals is remarkable, a fact which is attributed largely, if not altogether, to the reliability of the operators themselves. It is claimed by English signal engineers that in such a country where there is such extreme heaviness of traffic that the manual is the only system practicable, and this fact along with the highly satisfactory results of such a system accounts for the reluctance on their part, to adopt any system entrusted entirely to mechanical operation.

The disadvantages, apart from expense, inherent in the manual system are few and small. The advantages are manifold. Trains are absolutely spaced and enginemen cannot "run" signals without detection. Permissive blocking is only allowed when apparatus is seriously out of order, which only happens when inspection is poor. If locks fail there is bell communication between towers. If these fail there is the telegraph in complete installations to fall back on. Wrecks, derailments, etc., are easily reported, so that aid may be quickly summoned and trains running on parallel tracks stopped and protected. Any dangerous defects in condition of trains may be noted by towermen and reported to those in advance.

Automatic signals have reached such a stage of perfection that their reliability can no longer be questioned. A million operations of a signal with only one false clear indication, ought to be sufficient to dispel doubt as to their reliability. The efficiency of their working depends almost entirely upon the inspection of the apparatus. The main defect of the automatic signals is that the protection of switches is incomplete. The switches are included in the circuit and have a bell or indicator attachment by which the position of the signal at the beginning of the block is known to the trainmen at the switch. It is possible that trainmen may not observe the indicator, or that the bell may fail to ring by poor adjustment, or by getting broken by mischievous trespassers, so that train using the switch has no warning of another train, which may have already passed the protecting signal and entered the section.

It is sometimes stated that enginemen disregard automatic signals, there being no one to report them. As a matter of fact

this is seldom done. A sane engineman is not going to plunge recklessly into danger when by waiting a specified time at a block signal set at danger, he may then proceed with caution through the block to the next, where he is likely to find the line clear.

The advantages of the automatic system are perhaps not as numerous as those of the manual; a train broken in two is fully protected; broken rails, if rail circuit is used, usually cause signal to go to danger. The former system has decidedly a great advantage over the latter in point of cost, and in this respect it is the most suitable for roads with great mileage and heavy traffic running through open country. The maintenance of both is about the same, but the cost of operation is a factor which does not occur in the automatic, but which is constant in the manual system. For this reason blocks are often too long to give prompt handling of the traffic. With the automatic system the blocks may be made as short as required without materially increasing cost of maintenance, the first cost of installation being practically the only expense to be taken into consideration.

The paramount objection raised by English railroad men against automatic signals of all kinds, is not that they are unsafe, not that they are costly or troublesome in care and maintenance, but rather that the exigencies of heavy traffic prove too much for them thereby causing delay.

The question of the relative merits of the two systems resolves itself into a straight question; which one will operate 100,000 or 1,000,000 times with the least number of unnecessary stoppages of trains. The Railroad Gazette of January 24, 1890, says, referring to the use of a form of automatic signal on a line of heavy traffic: "Going since May 30, 1888, and being used as a positive block signal, it has never got out of order, caused an unnecessary stop, or shown safety when danger existed, thus making a remarkable mechanical record."

Other Systems of Signaling.

There are other schemes by which trains are kept spaced. These are of less importance, being used on roads of light traffic where demands for which handling of trains are not sufficient to

warrant the expense attached to installing complete signal systems. Many roads of light traffic still use the "time interval" as a means of keeping their trains spaced. But the protection of a train that has unexpectedly come to a stop by the ordinary method of sending a man back with a visible or audible signal, is unsafe, except when carried out by men of best judgment. Both the flagman who is to give the signal and trainmen of the following train must never fail to practise the most extreme caution; and as safety is always contingent upon the flagmen having sufficient time to get back to warn following train, another element of danger is introduced. The great deficiencies of this system are all well understood by railroad men. Much of the loss of life, and collisions, are due to ineffective flagging caused by sheer neglect of trainmen to whose judgment is entrusted practically the running of the trains. But while admitting that the time interval system is an unsatisfactory protection for trains, many roads in this country have had to deny themselves the advantages of the block system on account of the cost attached to it.

The Train Staff or Tablet System.

A modified form of the block system is found in the train staff or tablet system. These are exactly the same in principle, the apparatus being somewhat different. It is an old English idea, the track being divided into blocks or sections, and before a train can pass over a block it must have in its possession a metallic tablet or train staff.

The apparatus of the staff system consists of a receptacle for holding a number of metallic staffs, one of which is given to each engineman to authorize him to proceed over a specified length of track. There is a receptacle or "pillar," as it is called, at each end of the block section, and these two are electrically connected or interlocked, so that two staffs cannot be out at the same time. Such a system is only used on single track over short sections.

The sections are laid out varying from 4 to 20 miles in length, according to the distance between towns on the line, a tablet station being established at each.

The electric tablet instrument containing the tablets, is placed at each station which defines the blocks. Before a tablet can be obtained from the instrument at either end of a section, the consent of the operators at each end of the section must be given, and only one tablet can be taken out of the two instruments of a section at a time, so that trains travelling in opposite directions are fully protected.

The tablet is placed in a leather pouch before being handed to the train driver, who, in turn, delivers the tablet for section just travelled. This necessitates trains to come almost to a dead stop before exchanges can be made. Apparatus was invented by which a train running 40 miles an hour could catch up and deliver tablets, thus allowing through trains to proceed without a stop.

The tablet system is sometimes used with the block system where it is desired to suspend the latter temporarily and do permissive blocking. In order to pass a block signal set at danger, it is necessary for the engineman to procure a permissive tablet, which gives him running power over the section protected by the suspended block signal.

Interlocking at Grade Crossings.

A word or two might be said upon the protection of grade crossings. It is done by a system of signals and derailing switches. Experience has taught the best location for the signals, the number, and safeguards necessary in case a train should pass the danger signal.

Figure 11 shows plan of simple grade crossings. Figure 11 (a) represents a single track diamond crossing. The distant signals shown with fish-tail ends are placed 1,200 feet from the home signals, and in each case to the right hand of the track. In case a train should pass a home signal set at danger, the last precaution taken is a derail placed 50 feet from the home signal and about 300 feet from the centre of the diamond.

The signals and derails are operated entirely from a signal tower, there being pipe and wire connections between each and levers in the tower. It is common practice to have the distant

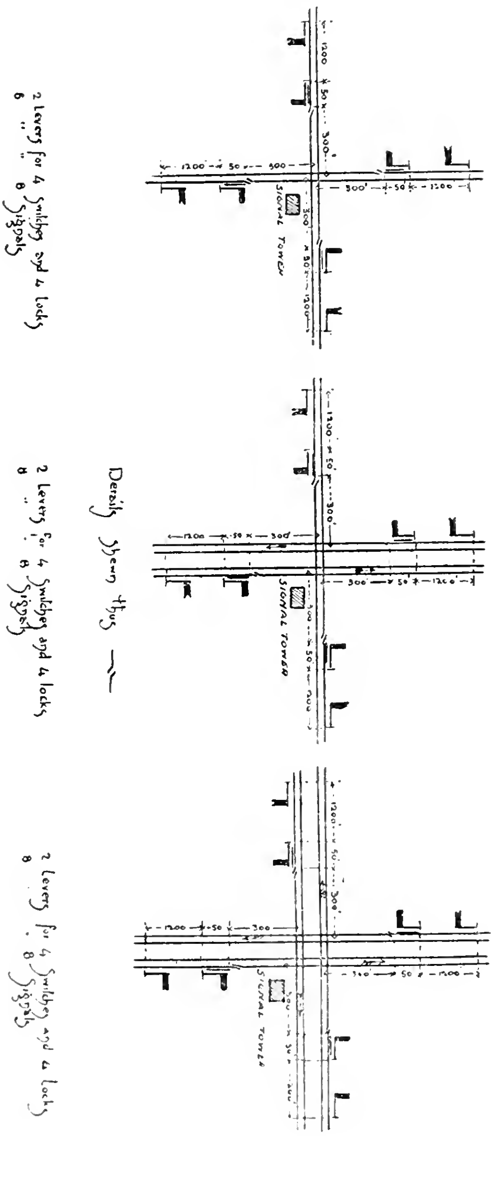

2 Levers for 4 Switches and 4 locks
8 " " 8 Signals
SIGNAL TOWER
Details shown thus
2 Levers for 4 Switches and 4 locks
8 " " 8 Signals
SIGNAL TOWER
2 Levers for 4 Switches and 4 locks
8 " " 8 Signals
SIGNAL TOWER

Fig. 11

signals lock their home signals in the clear position. One lever operates a pair of derails on each track. The signal levers are so interlocked that only one track can have its signals cleared at a time.

The installations for double tracks are obviously as simple as those for single track; in the latter case trains being supposed to run always in the same direction on same track.

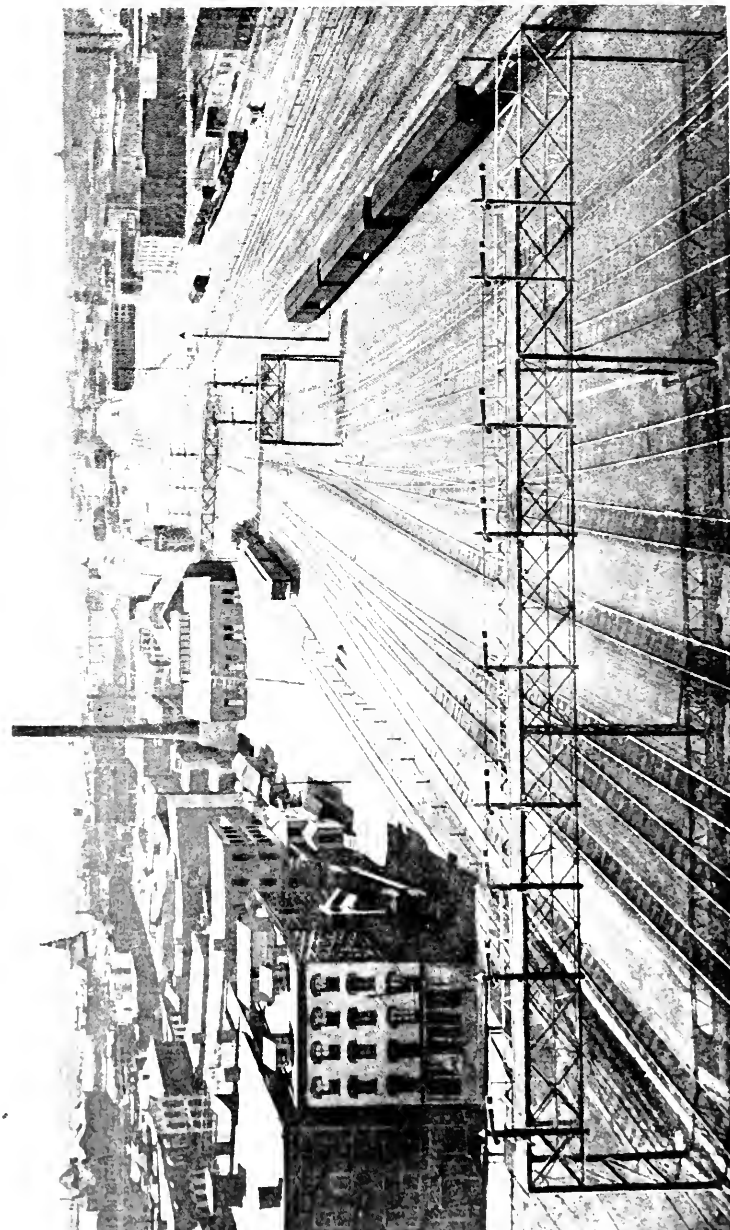
Although the high cost of installation and operation has deterred lines from installing these plants, it has been found that the time saved would often warrant the expenditure even on lines of light traffic. In cities where all sorts of crossings are encountered, such plants are an absolute necessity, at any cost. Where track crossings and junctions become complicated, manual power for working the levers is dispensed with in the most recent installations. The use of electricity in combination with compressed air, affords the speediest and most reliable means for handling of trains.

Yard Signaling.

Before concluding these remarks reference might be made to signaling in yards. This is a subject in itself, being one in which difficult problems arise, as in the case of great complications of tracks, where one road crosses another in the vicinity of large yards, or makes junctions or borrows track. Such problems are left for solution to the signal engineer who devises schemes for a systematic operation of switches and signals, the former affording a means of transit from one track to another, the latter protecting trains while performing this operation.

The mechanical side of yard signaling, involving as it does interlocking, is too great to admit of discussion here, so only a few general principles will be referred to.

As the main lines for incoming or outgoing trains are often run through the yards themselves, it is of the greatest importance that signals governing them (main lines) should be absolutely placed. The most common way of placing them is on a light bridge or superstructure, placing signal directly over the track it governs. Where the block system is in use the sections are



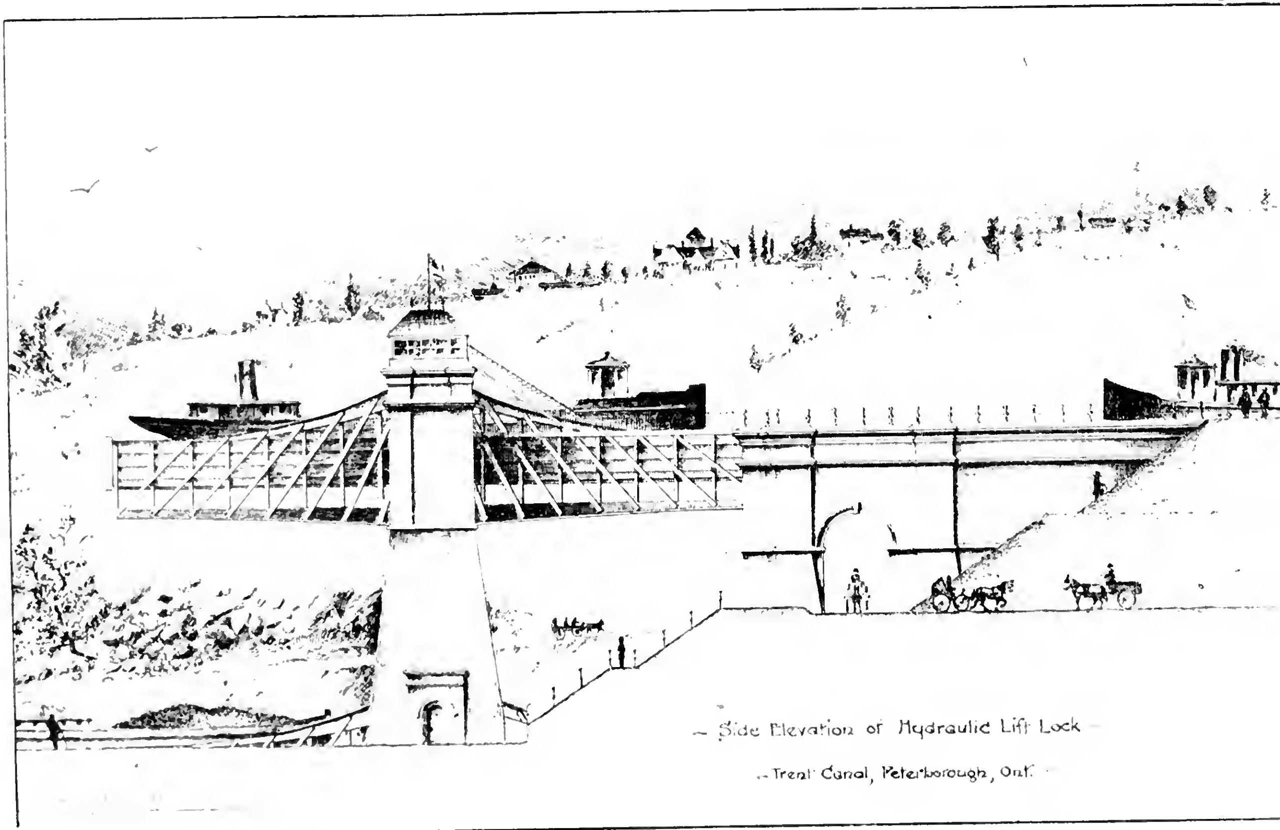
short, from one-third to one-half mile in length; signal cabins are placed at the beginning and end of each, where they serve also the purpose of interlocking cabins for main line switches. Each of the cabins has electrical communication between one another, and sometimes between the train starter. As trains run slowly through yards "permissible blocking" is allowed in most cases, there being practically no danger caused by it.

Signals.

The signals are of the semaphore type, distant signals being unnecessary on account of slow speed of trains. They are commonly worked by levers in towers, having pipe and wire connections. The most perfect installations are now operated by the electro-pneumatic system, which, of course, is far superior to hand power levers. It is only in cases of great complication of tracks and switches that these installations are made. The great advantage of the electro-pneumatic system is that signals may be operated at greater distances, and one man can do the work of many in the interlocking towers.

Automatic block signaling may be done advantageously in yards, preferably by the use of compressed air and electricity. One air compressing plant will suffice for the operation of signals of the largest yard. Figure 12 is a cut of a yard whose signals are operated by electro-pneumatic block signals, which stand nominally at danger. The signal bridge in the front of the picture marks the beginning of a section, the two blocks being visibly defined by the two signal bridges in the distance. Interlocking cabins provided with electro-pneumatic levers operate the switch signals and switches. At important road crossings small cabins are built for signal men, whose business it is to operate the gates and give flag warnings.

INDEX TO THE FIRST FOURTEEN NUMBERS.



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PREFACE.

It is with no little satisfaction that this, the fifteenth annual edition of the proceedings of the Engineering Society of the School of Practical Science, is presented to the members. The high standard set in previous editions is quite equalled by the quality of the papers here published. It is an evidence of the *esprit de corps* characteristic of "School" men that the graduates of our college have the will to find the time and energy necessary for the preparation of essays for the information and inspiration of our members. Special attention might be drawn to the papers of Messrs. Haultain and Mitchell dealing with the relation of the young graduate to his profession. The discussion by Mr. MacMurchy defining a special relation of the engineer to his employers is also noteworthy. Two very practical papers are those of Messrs. Thomson and Francis, the one describing an up-to-date method of solving a "ticklish" problem; the other giving information upon an interesting and unique part of the construction of one of our newest highways of commerce.

Let the motto of the Society, as well as of the School, be ever: *Scite et Strenue.*

This edition consists of 1,500 copies.

W. G. CHACE.

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McGowan, J., B.A., B.A.Sc., '95.

McKinnon, H. S., B.A.Sc., '95.
McKay, O., O.L.S., '85.
McKay, W. N., '95.
McMillan, J. G., B.A.Sc., '00.
McPherson, A. J., B.A.Sc., D.L.S., '93.
McPherson, C. W., O.L.S.
McTaggart, A. L., B.A.Sc., '94.
McVean, H. G., '01.
Merrill, E. B., B.A., B.A.Sc., '90.
Middleton, H. T., '01.
Milne, C. G., B.A.Sc., '92.
Mines, W. H., B.A.Sc., '93.
Minty, W., B.A.Sc., '94.
Mitchell, C. H., B.A.Sc., C.E., A.M. Can. Soc. C.E., '92.
Mickle, G. R., B.A., '88.
Mollins, C. B.
Moore, J. E. A., C.E., '91.
Neelands, E. V., B.A.Sc., '00.
Newman, W., O.L.S., A.M. Can. Soc. C.E., '91.
Paterson, C.E.
Pinhey, C. H., D. & O.L.S., '87
Piper, A. G.
Proudfoot, H. W., '97.
Raymer, A. R., '84.
Richards, E., B.A.Sc., '99.
Richardson, G. H., '88.
Robinson, F. J., D. & O.L.S., '95.
Ralph, H., '94.
Rose, K., '88.
Rosebrugh, T. R., M.A., '89.
Ross, J. E., D. & O.L.S., '88.
Ross, R. A., E.E., '90.
Russell, T. S., O.L.S.
Scott, W. F., '97.
Shanks, Thos., B.A.Sc., '99.
Shaw, Jno. H., O.L.S.
Shields, J. D., B.A.Sc., '94.
Shillinglaw, M. H.
Shipe, R. R., '96.
Shipley, A. E., B.A.Sc., '98.
Sifton, E. I.
Silvester, G. E., O.L.S., '91.
Sims, H. B.
Smith, Angus, O.L.S., '94.
Smith, A. H.
Speller, F. N., B.A.Sc., '93.
Squire, R. H., B.A.Sc., O.L.S., '93.
Stern, E. W., '84.
Stewart, L. B., D.L.S., D.T.S.
Stocking, F. T., '95.
Stovel, R. H.
Stull, W. W., B.A.Sc., O.L.S., '97.
Symmes, H. D., '91.
Taylor, W. V., '93.
Tennant, D. C., B.A.Sc., '99.
Thomson, T. K., C.E., M. Am. Soc. C.E., '86.
Thomson, R. W., B.A.Sc., '92.
Tremaine, R. C. C., B.A.Sc., '95.
Troupe, G. E.
Tye, A. T.
Webster, E. B.
Weldon, E. A., '97.
Wickson, F. R.
Wilkie, G.
Wright, C. H. C., B.A.Sc., '88.

ORDINARY MEMBERS.

Acres, H. G., '03.
Alexander, J. H., B.A., '03.
Alison, J. G. R., '03.
Allen, C. W., 04.
Angus, H. H., '03.
Arens, H., '04.
Baldwin, F. W., '04.
Baldwin, G. W., '04.
Bangham, J., '04.
Barber, H. G., '02.
Barrett, J. H., '04.
Beatty, H. E., '04.
Beatty, J. A., '03.
Begg, W. A., '04.
Blaine, T. R., '04.
Blair, W. J., '02.
Boeckh, J. C., '04.
Bonnell, M.B., '03.
Boswell, M. C., '00.
Bowles, G. W., '04.
Brandon, E. T. J., '01.
Bridgeland, M. P., B.A., '03.
Brown, J. H., '02.
Brown, T. E., '04.
Bryce, R. A., '04.
Burd, J. H., '03.
Burgess, E. L., '03.
Burley, R. J., '04.
Burnham, F. W., '04.
Burwash, N. A., '03.
Calder, J. W., '04.
Cameron, N. C., '04.
Campbell, A. J., '04.
Campbell, A. M., '04.
Campbell, A. R., '02.
Campbell, W., '02.
Cass, G. A., '04.
Challies, J. B., '03.
Chace, W. G., '01.
Chase, A. V., '04.
Chilver, C. W., '04.
Chilver, H. L., '04.
Christie, N. W., '04.
Christie, W., '02.
Coates, P. C., '04.
Cockburn, J. R., '01.
Code, S. B., '04.
Code, T. F., '04.
Conlon, F. T., '02.
Connor, H. V.,' 02.
Corbett, J. T., '03.
Coulson, C. L., '03.
Cousins, E. L., '04.
Cowan, W. A., '04.
Craig, S. E., '04.
Crerar, S. R., '04.
Culbert, M. T., '02.
Cumming, R., '02.
Currie, W. M., '04.
Davison, A. E., '03.
Depew, H. H., '03.
Douglas, W. E., B.A., '02.
Dunlop, R. J., '02.
Dunn, H. C., '04.
Eason, D. E., '01.
Edwards, W. M., '02.
Elder, A. J., '04.
Elwell, W., '02.
Empey, J. M., '02.
Evans, H. W., '04.
Fee, T., '04.
Fensom, C. J., '03.
Field, J. J., '04.
Fleck, J. C., '04.
Fletcher, H. M., '04.
Forbes, D. L. H., '02.
Ford, A. M., '04.
Ford, E. A., '04.

Foster, W. J., '04.
Fuce, E. O., '03.
Gaby, F. A., '03.
Gardner, J. C., '03.
Gibson, A. E., '02.
Gibson, W. S., '04.
Gillespie, P., '03.
Goodall, J. N., '04.
Goodwin, A. C., '02.
Gordon, J. P., '03.
Gordon, W. C., B.A., '03.
Gourlay, W. A., '03.
Gray, A., '03.
Gray, W. W., '04.
Greene, E. A., '04.
Greenwood, W. K., '04.
Gzowski, H. N., '03.
Hamilton, J. T., '03.
Hanes, G. S., '03.
Hara, L. D., '04.
Harcourt, F. T., '03.
Harris, C. J., '04.
Harvey, Chas., '01.
Hayes, L. J., '03.
Hellmuth, H. I., '04.
Henderson, F. D., '03.
Henderson, T. D., '04.
Henry, J. S., '02.
Henwood, C., '02.
Heron, J. B., '04.
Hill, E. M., '04.
Hill, S., '04.
Holmes, O. B., '04.
Horton, J. A., '03.
Horwood, H. O., '04.
Howard, J. A., '04.
Ingles, C. J., '04.
Irving, T. C., '04.
Jackson, E. R., '04.
Jackson, J. G., '03.
Jackson, J. H., O.L.S., '03.
James, E. A., '03.
Jamieson, C. W., '04.
Jermyn, P. V., '04.
Johnston, C. K., '03.
Johnston, D. M., '02.
Johnston, J. H., '03.
Johnston, J. W., '04.
Keefe, W. S., '04.
Kernahan, M. G., '03
Knight, R. H., '02.
Laing, P. A., '04.
Lang, A. G., '03.
Larkworthy, W. J., '03.
Latornell, A. J., '03.
Legate, W. B., '04.
Legge, A. H., '04.
Little, J. C., '04.
Mace, F. G., '02.
Mackay, J. J., O.L.S., '03.
Mackay, J. T., '02.
Mackenzie, C. H., '04.
Mackenzie, K. B., '04.
Madden, J. T., '02.
Maddison, W. W., '04.
Manchester, C. S., '04.
Manson, C. J., '04.
Marquis, G. P., '04.
Marriott, F. G., '03.
Marrs, C. H., '02.
Mathison, P., '02.
Maus, C. A., '03.
McAuslan, H. J., '03.
McBride, A. H., '02.
McCuaig, O. B., '04.
McEwen, D. F., '04.
McEwen, G. C., '04.
McFarlane, J. A., '03.
McGibbon, C. P., B.A., '04.
McKay, C. D., '04.
McLennan, A. L., '02.
McMaster, A. T. C., '01.
McMillan, D., '04.
McNaughton, A. L., '03.
Mennie, R. S., '02.
Merritt, R. N., '04.
Miller, M. L., '03.
Mills, J. E., '04.
Milne, W. J., '03.
Mitchell, P. H., '03.
Montgomery, R. H., '03.
Moore, E. E., '04.
Moore, F. A., '02.
Moore, H. H., '02.
Moorhouse, W. N., '04.
Morden, L. W., '04.
Morley, R. W., '02.
Morton, P. E., '03.
Mullins, E. E., '03.
Munro, C. G., '04.
Munro, W. H., '04.
Nash, T. S., '02.
Nevitt, T. H., '03.
O'Brien, D. E., '04.
Oliver, E. W., '03.
Oliver, J. P., '03.
O'Sullivan, J. J., '04.
Pace, G., '04.
Pace, J. D., '03.
Pardoe, W. S., '04.
Park, J. P., '04.
Patten, B. B., '03.
Peaker, W. J., '04.
Phillips, E. P. A., '04.
Philp, D. H., '03.
Pickering, A. E., '04.
Pinkney, D. H., '03.
Plunkett, T. H., '03.
Porte, W. B., '03.
Powell, G. G., '02.
Price, H. W., '01.
Pullen, E. F., '04.
Ramsay, G. L., '04.
Ratz, W. F., '02.
Raymon, D.L.C., '04.
Reid, F. B., '04.
Reynolds, G. B., '04.
Riddell, M. R., '04.
Rigsby, J. P., '03.
Robertson, H. D., '02.
Robertson, D. F., '03.
Robinson, L., '04.
Roddick, J. O., '04.
Rogers, W. R., '04.
Ross, R. B., '03.
Roxburgh, G. S., '04.
Rundle, L. P., '04.
Rust, H. P., '01.
Rutherford, F. N., '03.
Sander, P. M., '04.
Sauer, M. V., '01.
Schell, F. S., '04.
Scott, G. S., '04.
Serson, M. V., '04.
Seymour, H. L., '03.
Shepley, J. D., '04.
Shipe, H. M., '03.
Sinclair, D., '02.
Slater, F. W., '04.
Small, H. S., '03.
Smallpeice, F. C., '98.
Smart, R. S., '04.
Smith, D. A., '04.
Smith, H. G., '03.
Smith, J. H., '08.
Smither, W. G., '04.
Southworth, H. S., '04.
Steele, T. J., '02.
Stevenson, W. H., '01.
Stewart, M. A., '03.
Stover, C. B., '04.
Street, P. B., '04.
Stroud, A., '04.
Sutherland, W. H., '02.
Sykes, F. H., '04.
Tait, B. J., '04.
Tait, E. L., '04.
Taylor, T., '02.
Teasdale, C. M., '02.
Thompson, H. P., '04.
Thomson, J. E., '04.

ORDINARY MEMBERS—*Continued.*

Thomson, S. E., '04.
Townsend, C. J., '04.
Townsend, D. T., '04.
Trees, S. L., '03.
Trimble, A. V., '04.
Tucker, B. B., '04.
Umbach, J. E., '03.
Vaughn, J., '04.
Wade, E., '04.
Waldron, J., '03.
Walker, E. W., '04.
Wanless, A. A., '02.
Wass, S. B., '03.
Watson, J. P., '04.
Weddell, R. G., '04.
Weir, J. M., '04.
Wells, A. F., '04.
Whelihan, J. A., '03.
White, H. F., '03.
Wickett, W. E., '04.
Wilkie, J. H., '04.
Williams, C. G., '03.
Wilson, J. M., '04.
Wilson, N. D., '03.
Wilson, W. H., '04.
Worthington, W. R., '03.
Wright, R. T., '94.
Wright, W. F., '04.
Yeates, P. M., '04.
Young, C. R., '03.
Young, W. H., '03.
Zahn, H. J., '02.

OBITUARY NOTICE.

During the present term the grim reaper, Death, has removed one of our undergraduate members, William Edward Costin, who died January 16th, 1902. For several months he suffered from a sarcomatous growth which finally baffled the best medical skill that could be procured.

He was the only son of W. I. Costin, M.D., and was a native of Oxford county. After attaining senior leaving standing at Woodstock Collegiate Institute, he taught for about three years, and then entered S. P. S. in a course of Civil Engineering with the present graduating class, obtaining honor standing in his first and second years.

On account of his many winning qualities he made many warm friends among the students, who feel that they have lost a true and noble-hearted schoolfellow.

We regret to have to record the death of another of our undergraduate members, John A. Nelson, a student in the Mechanical and Electrical Department of the first year. He was the youngest son of Mr. J. C. Nelson of St. Catharines, and was a general favorite among those who made his acquaintance during his short term here.

He was taken ill on Wednesday, January 1st, 1902, with appendicitis, and, after a week of intense suffering, died at the home of his parents.

ENGINEERING SOCIETY

OF

The School of Practical Science

TORONTO.

PRESIDENT'S ADDRESS.

GENTLEMEN: As this is the first occasion on which it has been my pleasure to meet the Engineering Society since you did me the honour of electing me President of this honourable body, I welcome the opportunity of thanking you for the confidence you have placed in me. The Engineering Society has been presided over by men who have achieved the highest success in the engineering world. Our Society represents a School of Engineering which is second to none in Canada. These things impress upon me the weight of responsibility I have assumed in accepting this office. But I am reassured when I consider the strong, energetic committee with which you have surrounded me; and with your hearty co-operation, we shall endeavour to continue that progress which has so markedly characterized the history of our Society.

I would call your attention to the great interest taken in the department of engineering, as evidenced by the increasing number of students entering each year. To the gentlemen of the first year who are about to become members of our Society, I would extend a hearty welcome. Enter at once into the life of the Society. Do not wait till your second or third year, to feel that you are a part of its workings. It is unnecessary for me to go into a discussion of the objects of the Society, or the advantages to be gained by contributing papers. These have been very thoroughly laid before you in the addresses of a number of our former Presidents. It will pay you to read them up. Suffice it to say, that the Society needs your help and you need the Society's help. To these ends I would ask you to take an interest in everything pertaining to the

Society, contribute a paper if you can, ask questions and be ready for a discussion after every paper that is read.

The Engineering Society being representative, as it is, of the whole student body of the School of Practical Science, I wish to refer to a few things of general interest.

During the past year there occurred an event which will remain a landmark in the history of our institution. I refer to the banquet tendered by the graduates and undergraduates of the School to our honoured Principal, on the twenty-first anniversary of the birthday of the School of Practical Science. The gathering was a most representative and enthusiastic one, indicating the high esteem in which our Principal is held.

At the conclusion of his address on that occasion, Principal Galbraith made an important announcement. To use his own words: "A week ago the Senate of the University passed a statute which provides that the School of Practical Science, the teaching staff, examiners and students, together with examiners for the degrees in applied science and engineering, shall ex-officio constitute the Faculty of Applied Science of the University of Toronto. By this statute the powers of the Senate with reference to the degrees, and those of the School with reference to the curriculum and work of instruction, as also the statute respecting affiliation, remain unaltered. The result is that the University gains without expense a fully equipped Faculty of Applied Science, and in this respect puts itself on an equality with the other great Universities of the continent; while on the other hand, the School gains public recognition of the fact that its work is of equal rank and dignity with that of the ancient faculties of Arts, Medicine, and Law. This action of the Senate forms a fitting close to the history of the School in the nineteenth century."

In view of the fact that we are now a full fledged faculty, on equal standing with the faculties of Arts, Medicine, and Law, it behooves us that we enter more fully into the student life of our great University.

In respect to athletics no fault can be found. "School-Cups!" has been the war-cry which has cheered on to victory our athletic champions on many a hard fought field. There are, however, other phases of University life into which we do not enter with such zeal. We might mention the Varsity paper, an excellent publication, in

which we should manifest a greater interest. The Dining Hall and the Students' Union are new departures, and should be powerful agents in cementing the union of the different faculties. In loyalty to the School our men have been true to the core. Let us now extend our sympathies, and without lessening in the least our love for old S.P.S., let us join with a fervor characteristic of school men, in sounding the fame of this great University of which we form no unimportant part.

The upper years of the School will remember that last spring an enthusiastic delegation from this institution crossed over to the Parliament Buildings and made representations to the Government setting forth the urgent needs of the School. They will also remember that later the Legislature decided to devote $200,000 to Science, $50,000 of which was to be immediately available. During the summer Professors Galbraith and Wright visited many of the American Universities, inspecting the Applied Science Departments with a view to the best methods of constructing and equipping the new buildings. Also J. W. Bain, B.A.Sc., who has been in Europe the past summer, visited the chemical departments of a number of the universities on the continent, with the same end in view. They have submitted their report to the Government. The Provincial architect is busy preparing plans to be submitted to the Council for their approval; and it is probable that the contract for the construction of the new building will be let this Fall. The site of the new building will be somewhere in the vacant plot owned by the University on College Street. It is to be hoped that every effort will be put forth by the Government in order that the new building will be constructed as soon as possible. We all know that already, owing to the insufficient accommodation, small teaching staff and poor experimental equipment, that the needs of the students are far from being supplied..

As a result of the energetic efforts of Capt. Lang and Lieutenant Burnside, the Toronto Engineer Corps is now a reality; and a striking reality it proved itself to be during the recent visit of the Royal Party. In the Royal Review on Friday, the Duke remarked on the smart appearance of the company, and during the afternoon of the same day while forming a "Guard of Honor" for the Royal Party on their visit to the University, it again came in for con-

gratulatory remarks. The company at present musters fifty-eight men, and nearly all are men of the School of Practical Science. We shall hope that before long their numbers may be doubled. When the men have all qualified in drill, the chief work which is the specialty of an Engineer Company will then be proceeded with. This work consists of field work, earthing, use of spar, bridging, etc. Good advancement may be expected, considering the speed with which the preliminary drill was mastered. A full supply of engineering stores has been provided, including outfits for signalling and telegraphing.

There has been some discussion, perhaps some dissatisfaction, in regard to the Library of the School. The following may prove some enlightenment on the subject. The chief officer is the Librarian appointed by the Council, who is made responsible for the management of the Library over which he has control. The students elect by ballot at their general elections two representatives—first and second assistants—who do the actual work in connection with the Library. A catalogue has been printed and is accessible to all members of the Society. In this catalogue, opposite the names of the volumes, are letters indicating the libraries of the Professors in which the volumes may be found. Where no letter occurs opposite the volume, it will be found in the General Library of the School. The volumes in the respective libraries of the Professors are permanently located there. These books may be procured subject to the ordinary regulations, by applying to the Professor. Each Professor in this way acts as an assistant librarian.

We are all glad to know that the health of our Lecturer in Applied Mechanics, Mr. Duff, has so far improved that he is able to resume his duties in the School. We all join in welcoming him among us, and trust that we may have his genial presence at our meetings in the coming year.

I might call your attention to the appointment of Mr. Monds to the position of Demonstrator in Mechanical Engineering, to that of Mr. Chace to the Fellowship in Electricity, to that of Mr. Craig to the Fellowship in Mechanical Engineering, and to that of Mr. Ardagh to the Fellowship in Chemistry.

In preparing this paper on "Engineering as a Profession," I cannot claim entire originality. My experience so far has been

limited, and if you find some of my ideas too far advanced for a Fourth-Year man, I can plead with Kipling—

> When 'Omer banged his bloomin' lyre,
> E'd 'eard men sing by land and sea;
> And what 'e thought 'e might require,
> 'E went and took the same as we.

ENGINEERING AS A PROFESSION.

The profession of engineering is an honoured and honourable one, but its place in the public estimation is not yet where its merits and services would place it. In Europe the standing and remuneration of the engineer are second to those of no other professional man. England recognizes the services of her engineers by honours and emoluments. The Engineers of the Forth Bridge were knighted in recognition of their services. Public measures and acts of parliament are largely influenced by their advice and direction. Manufacturing and industrial operations are largely managed by engineers instead of so-called practical men.

When John Smeaton, a little more than a century ago, became the first man to write Civil Engineer after his name, the title gave no prestige to the possessor. The early engineers, Watt, Stephenson, Smeaton and Fulton, had to fight their way through poverty and discouragements to a recognition of their services.

Canada and the United States are very slow in the recognition of the valuable services of their engineers. Either country owes more to the engineer than to any other class of equal numbers. Think of the immense development in any of the different branches. To follow out any one of the numerous lines of work in which he has been engaged, to trace the development of the first crude mechanism, up to the splendid triumphs of the present day in almost any department of industry, would be no idle task.

Engineering is a profession in which a man can be honourable. It is fascinating from the fact that one sees the realization of his mathematical and scientific theories and deductions. Its objects are useful in the highest degree. It is healthful and ennobling in its practice. In fact it is a profession which may well challenge the attention of the young man of earnest endeavour, who is seeking not only material prosperity, but an honoured place among those who have well served their day and generation.

Mr. Charles T. Harvey, an eminent engineer, in a paper read before our Society, said:—"Engineers of the highest degree are born not made. Technical education is helpful, but not determinative of the quality or strength of the will power which you need to best succeed in your profession. You have chosen a profession which calls for intense exercise of trained will power, as its functions are to re-arrange the material features of the earth to serve human purposes to a higher degree. The embankment of a railway, the prism of a canal, and the mechanism of a steam or electrical engine, are triumphs of educated will power over matter."

One great factor very necessary in the make up of a successful engineer is the power of observation. The observation of a simple fact, and the train of thought induced thereby, have led continually to important results. The ability to map localities in the mind, the faculty of noting the workings of a piece of mechanism, the observation of leading features of places and things; all of these are of the utmost value to the engineer. This power, combined with a sound knowledge of natural and mechanical laws, together with a sufficient amount of nerve to put the thing into execution, are the great requisites of an engineer.

The engineer should love his profession. The most simple operations should possess an attraction to him. The application of his theoretical knowledge, both in mathematics and science, should be beautiful to him. The man who sees only the theoretical truth of the fundamental formulae, and has no love for their application, should not adopt engineering as a profession. Obstacles that spring up along the line should not dampen his ardour to obtain a true result.

The engineer should honour his profession. After becoming as proficient as possible in the department which he has chosen, honour and honesty should characterize his policy. When the engineer accepts bribes from the contractor for passing work which does not fulfil the specifications; when he charges his employer a fee for first-class work when he knows it is inferior; when he adopts the practice of "making days" when the "per diem" prescribed by law is too small, he had better blot the name of his profession from his card and devote himself to a trade in which honourable dealing is not expected.

The final success of an engineer probably depends upon more qualities than are absolutely required in most of the other professions. His knowledge must be thoroughly technical, while his methods must be perfectly practical. The clergyman or lawyer is tolerably sure of success, if he is eloquent and respectable. The physician who has an engaging manner, need not be a great practitioner in order to secure a good income. But the engineer, in order that he may attain to success, must possess qualities which would have won much more fame and fortune if they had been applied to some other calling.

A prominent engineer of the day has put it thus: "The demand to-day is for men who can accomplish specific results; not the ancient history of the steam engine, but the ability to construct the most modern and complete form; not the story of how Franklin discovered the relations of lightning to the electric fluid, but the ability to design and construct a dynamo that will run the greatest number of lights at the least expense; not how the subject of alchemy has developed into modern chemistry, but how to conduct industrial manufactories with the least possible waste."

The demands of engineering upon the man are greater than in most of the professions. He must first submit himself to a thorough technical training, in order that he may be able to read and observe. Having secured his diploma, he must seek employment that he may obtain experience, for the glimpse of the real thing which he has got in his college course is far from fitting him for the responsibilities of the work. During the earlier part of his career he will probably find that his work is something more than trying.

The worst feature of the engineer's life is its uncertainty. Especially is this true of the mining and civil branches. One must at all times be in readiness, at a moment's notice, to go to any part of the country where his work may call him. Often he is exposed to great hardships in the way of extremes of heat and cold, rain and drouth, and sometimes scanty fare.

What does the Faculty of Applied Science offer to a prospective engineer? It offers that technical training which is so necessary nowadays in the make up of a successful engineer. "Knowledge is power" is an old adage, a back-number. Power is rather the ability to apply knowledge. Technical schools not only furnish knowledge, but train their students in the application of it. Just

here I would take the opportunity of referring the men of the First Year to Principal Galbraith's address at the Banquet last Christmas. The subject was, "The Function of the School of Applied Science in the Education of the Engineer." The subject is very thoroughly dealt with, and is especially adapted to us as students.

We in our technical training should aim at laying a broad foundation, rather than at specializing along some chosen line. Circumstances in most cases determine our specialization in after life. In fact, it is said by men of authority that a young man thoroughly grounded in fundamental principles and well trained how to apply them, has almost an equal chance for success in all branches of engineering. As a proof of the fact we only need look up the records of our own graduates.

What does the Engineering Society offer to the prospective engineer? I shall not enlarge very much on this, but refer you again to the addresses of our former presidents. With regard to papers, I would say, do not wait to be asked, but set to work and prepare one to be read before the Society during the coming year. The mere act of preparing a paper is a valuable discipline to the writer. Nothing serves so well in systematizing one's ideas, clearing up doubts and exposing deficiencies on a subject, as the compiling of a paper. The benefits which you receive from the Society. will probably depend on the amount of energy you invest in it. If you are simply looking to your own interests, without regard to the interests of others, probably neither will profit much by your presence. Let each member, without thought of year distinctions, feel that his part is necessary in order to make up the finished whole.

In conclusion, what are our professional prospects? In looking about Canada to-day one would say that the prospects never were brighter. Of course times are good, and one cannot tell how long they will continue. Engineering probably is the first profession to feel a depression, as great works are not usually undertaken when the country is suffering from hard times.

However, the immense developments in every kind of industry have created a great demand for competent and trained engineers. Capitalists are beginning to see the necessity of entrusting their great works in the hands of trained men. Let us all strive to come up to the standards required, and thereby render ourselves indispensable as well as honouring to our profession.

OUR TIMBER SUPPLY.

J. A. DeCew, '96.

The cost of material is generally the factor of prime importance in engineering construction, and the relative amount of each material used depends to a large extent upon its value, as well as upon its suitability for the purpose in hand. A structure which now contains certain proportions of wood, steel and concrete, might have contained these materials in quite different proportions had their respective values been differently related at the time. Therefore, if the cost of our timbers for construction and other purposes keeps steadily on the increase in the future as it has in the past, and if the price of iron, steel and concrete should remain comparatively constant, then the tendency of the future will be to abandon the use of wood as a constructive material, in proportion as its increased cost stimulates the employment of substitutes. What the ultimate result will be is hard to predict, as there are many variable influences to be considered. One thing, however, is quite certain, and that is, if we continue our present rate of consumption, the price of our timber must go on steadily increasing until its stumpage value becomes equivalent to the cost of reproduction.

If a species of timber should become exhausted before the equilibrium between consumption and reproduction is established, or if the demand for it should exceed the capacity of reproduction, then it is certain to become quite expensive and will only be employed for those purposes to which it is peculiarly adapted.

The cost of our timbers in the market may be expressed directly in terms of the cost of labour, supplies, stumpage and the distance between the market and stump. Therefore as we are rapidly consuming the present stand, which we might call our capital stock, the steady increase of the last two factors is sufficiently evident, and with these factors the price to the consumer must also advance.

As an example of a timber which will be commercially exhausted long before any adequate reproduction can take place, we might select the white pine. This is without question our most important and highly prized timber product, on account of its combination of qualities, which adapt it to an almost unlimited number of uses. The white pine is at home in commercial quantities, over an area of about 400,000 square miles, over which the original stand is estimated to have been about 700,000,000,000 feet, board measure. All that remains to us of this inheritance is about 110 billion feet, of which the Lake States (Michigan, Wisconsin and Minnesota) possess 64 billion and Canada about 40 billion. The annual cut in the Lake States is about 6 billion feet, and in Canada from 1½ to 2 billion feet, so that our total annual consumption is about 7½ to 8 billion feet. If this rate continues it is quite evident that all of our present stand of pine will be consumed in about 15 years. It is interesting to note in this connection that while the pine manufacturers of Canada have still from 20 to 25 years of stock in sight, the American mills can manufacture all of their remaining white pine in less than 10 years. Nearly all of the white pine is so located that the present rate of exploitation can be and probably will be continued until 75 per cent. of the present supply is cut, when, of course, the lack of logs will lead to a reduction in output. This curtailed output will begin on the American side in a very few years, and then the white pine will gradually cease to be the great staple of our lumber markets. This result is unavoidable, for if recuperative measures were immediately adopted, it would take 100 years to grow a pine tree, with an average diameter inside the bark of 15 inches, and to reproduce forests like those we are now consuming would take about 200 years.

It is erroneous to suppose that other conifers or hard woods may be substituted for or easily adapted to the uses of white pine, which is shown by a comparison with its most natural substitute, the southern pine. A shipping case, made of white pine, requires but half the effort to manufacture, and .5 to .65 the effort to handle or transport, as one made from hard pine, and as for lath, the white pine nails easier and shrinks less. For sash and doors the only satisfactory substitutes are cypress and white cedar, and these are not any too abundant themselves. Although from the scarcity of good

pine shingles, we are already using red cedar shingles from the Pacific coast, yet prices must reach a high mark before we can afford to freight lumber such a distance.

It is not only the white pine of which we might say, speaking relatively, that the end is in sight, for the same is true of the walnut, yellow poplar, ash and elm. As the elm and ash are particularly well adapted for the making of barrels, on account of their strength and toughness, the question of paramount importance to all those interested in cooperage stock is, what satisfactory substitute can be found for these fast disappearing woods?

In spite of the fact that there has been a great increase of late years in engineering construction, there has been no increase whatever in our annual consumption of timber. Nevertheless since the supply is decreasing faster than thedemand, we shall be forced in the near future to pay still higher prices for those wooden materials that we actually require. It is just this class of timber which we cannot well do without, that we shall find in future very hard to obtain. For although it does not take very long to grow railway ties or fence posts, we shall find it a very different matter to reproduce trees similar to those from which we obtain the wide clear lumber of our markets to-day.

Hemlock may make a fairly good substitute for pine in rough construction, but not for interior work.

Perhaps when the Isthmian Canal is completed, we shall be able to obtain our finest grades of lumber and shingles from the Pacific coast, but even that rich source of supply may in time become exhausted. The annual consumption of timbers, ties, fence rails, cordwood, etc., in the United States amounts to about 25 billion cubic feet. Their total forest area amounts to about 500 million acres, and on each acre it is possible to grow, according to German estimates, 55 cubic feet per annum, but of this growth only about 35 cubic feet is available to the American lumberman. Therefore, if all their forest area were well planted and managed, the annual harvest would not equal the annual consumption. But this possible state of reproductive efficiency is as yet but a dream of the future, and as our present stand is fast disappearing, it is the duty of everyone to conserve as much as possible the present supply. This can

be accomplished only by scientific lumbering, efficient fire protection, a more extended use of wood preservatives and an increased economy, along with the gradual substitution of other materials in construction.

Our wood consumption per capita, outside of fire-wood, is 8 to 10 times that of Germany, and 18 to 20 times that of Great Britain, for we rely more upon wooden structures than they do and are more wasteful in construction.

These facts go to show that we have yet plenty of opportunity to restrict the demand in proportion as the supply decreases, and in this way avoid future scarcity and excessive prices. However, not the engineer alone, but the community as a whole, has a direct interest in the perpetuity and conservative use of our forest resources, as well as in the preservation of favourable forest conditions, both in behalf of the agricultural interests of the country and on account of the resulting beneficial climatic effects.

FORESTRY AND ENGINEERING.

THOS. SOUTHWORTH.

My pleasure at being allowed again to read a paper before your Society is somewhat alloyed by the difficulty in presenting matter that will be new or interesting to the critical scientific minds comprising your membership.

Of course Mr. Barrett intimated that I would be expected to address you on forestry, but that is a large subject and presents too many phases to be treated as a whole, even hastily, in the time at my disposal.

In view of the number of letters I have received from various sources giving me advice on the subject of forestry in Ontario, the writers of which seem to regard the subject from such a different standpoint from my own, it has occurred to me that I might be permitted to define the term forestry as I understand it, speaking generally as applied to this Province. Forestry is primarily a system of farming with trees as the principal crop—I say principal crop advisedly—for they do not constitute the only crop in the forest. Forestry is not the mere preservation or protection of trees, nor the planting of trees where the country has been too much denuded, as it is quite often intimated

In farming with trees as the main crop, it is essential that the financial aspect should be had in view just the same as in other lines of farming. The farmer who raises wheat does so for profit, and when he harvests one crop he prepares for another. Just so with the forester, with the difference, in this country at least, that nature has started him with a grown crop ready to be harvested, and it is business with him so to harvest this original crop as to secure the largest financial returns from it consistent with the economical but effective reproduction of similar crops.

In Ontario we have to do with two main phases of forestry work, the one as it applies to the individual owner of woodlands,

the farm wood lot, and the other relating to the larger problem of the forest farm of the whole people on the Crown lands.

Both are important, both affect the general welfare of the Province.

The farmers of old Ontario, in clearing land to grow other and more valuable crops than trees, have removed the forest cover so completely as to seriously affect adversely the fertility of the land in some sections, and, through the drying up of our water sources, increasing the evaporation of moisture from the soil, and in other ways to seriously alter climatic conditions for the worse. At the same time, while the community in general suffers to some extent from this cause, the chief sufferer is the individual farmer himself. I will confine myself at present to a consideration of the larger and more important problem of forestry on the lands of the Crown.

By far the greater portion of the Province of Ontario is still tree covered. The land area of the Province is estimated at about 126 million acres. Of this less than 25 millions of acres are sufficiently settled to be under some form of municipal government. The balance, over 100 millions of acres, may be said to be tree covered. Of this immense area probably another 40 million acres is well suited for agricultural settlement, the rest being broken and chiefly valuable for mining and forest lands. The remaining 60 millions of acres is more or less tree covered and is all capable of growing trees. Mining development is now being prosecuted in several points in this area, and there will be many small villages and towns with the necessary agricultural settlement around them, but we may safely assume that this area will, or rather let me say should, remain permanently in forest—a vast forest farm the property of the whole people. Of the sixty millions of acres remaining, the greater part is still covered with its natural forest crop yet to be harvested; and from this will be seen the vastness of our resources in this line, and the desirability of solving the question of exploitation in the wisest way.

As I have said, forestry, or the growing and harvesting of trees for profit, is mainly a financial proposition, but there are certain other incidental advantages derived from the presence of trees in larger masses, in their effect on climate, water supply, and in other ways, such as to render it advisable that in some cases the mere

financial aspect should be subordinate. These incidental advantages concern the general public rather than the individual, and in the case of the individual holder of woodland, he cannot be expected to sacrifice his personal financial interests for the general good. For this and other reasons, it is wise that forestry on a large scale should be conducted by the State. A private holder might, under pressure of pressing financial need, realize on his forest wealth in a way inimical to the general welfare and disastrous to the industries dependent upon forest products. The State, on the other hand, is free from this danger, and is in position to disregard immediate profits where a close regard for them would adversely affect the general good in other ways. At the same time it is possible to retain these incidental advantages without sacrificing the purely financial results, and it is in this direction that the services of the skilled forester, the trained and scientific observer, will be required.

No formulated system of forestry, no matter how scientific it may be, will serve in this Province unless it is based on observation and practice under our own conditions. We have to solve our problems in our own way.

France and Germany and other European countries have elaborate scientific forestry systems that are well nigh perfect in their way, and for the countries in which they have been developed. They are the result of years of investigation and practice by scientific men; yet their systems are of little use to us except as forming a basis from which to study our own needs.

In our country, where only a third to a half of a small proportion of the more valuable varieties of trees have a market value, we could not afford to establish nurseries and transplant trees on a large scale, as is done in some parts of Europe, where the limbs, roots and even the leaves of the trees are marketable.

The cost of preparing the ground, planting the young trees, plus the cost of protection and care of the forests for 50 to 100 years, plus also the interest on the capital invested during that long period would, I fear, show a balance on the wrong side of the ledger when the crop was harvested. It is true conditions will be changed in this country before a crop planted now will be ready for harvest, but not sufficiently so as to make a financial success of tree planting by the State in a large scale.

However, if we have not much cash, we have plenty of time and plenty of land. A forest will inevitably reproduce itself if allowed to do so, and it is the business of the forester to assist Nature in securing a new crop in the shortest time and composed of the most valuable commercial varieties of trees.

Nature is sometimes slow in her methods and does not always accomplish the work in hand as we would have it done; yet in the reproduction of forests in Ontario, she is apt to reproduce a forest of the highest economic value. The most valuable tree from a commercial point of view in our original forests was the white pine, (Pinus Strobus), and in nearly all cases the forest planted by Nature after the original one has been cleared away by the axe of the lumberman and by fire, is largely composed of that tree. It is true that after a forest fire the first succeeding crop of trees is composed largely of poplar and birch, trees that seed yearly, and whose seeds are light winged and are carried miles by the wind; but these broad-leaved trees form the proper condition of shade, and fit the soil for the growth of the young pines that grow up under their protection, in all cases where any pine trees old enough to bear seed have been left in the neighborhood. The young pine plant is very delicate, and liable to extinction in the first few days of its growth, if exposed to the direct rays of the sun. Hence you will see that the presence of the forest weeds, the poplars and birches is necessary as a nursery for the more valuable sorts; and Nature is doing her work well in spite of, nay, in some cases, assisted by fire. That we can assist Nature and hasten the growth of the profitable forest is undoubted, and to apply the trained skill necessary for this object we require educated foresters.

Our forests, besides returning a direct annual revenue to the Province of over a million dollars, support, next to agriculture, by far our largest industry. Though not so attractive as mining, it has produced more wealth in Ontario than mining is likely to do for some time, and upon its continuance depends largely our prosperity. It is not too much to expect that in the not distant future, the best trained men from our scientific schools will find employment in managing the forest industries of the Province. We have no School of Forestry in Canada, though some three or four have been started in the United States. What we need is practical men whose scientific training has taught them how to observe.

It is largely a matter of observing, of finding out the "why" of things. A couple of years ago, in travelling through a pine forest with the superintendent of one of our large lumber firms, I picked up a considerable number of cones to see if there were any seeds left in them after they had fallen from the trees. Upon remarking that I had about concluded that the scales of the cone opened and the seeds dropped out before the cone fell off the tree, my companion remarked:—"Do you mean to say that there were seeds in them things? I have seen plenty of them lying on the ground for years, but never knew what they were." Now I cannot imagine a student of the S. P. S. walking over pine cones for 20 years, as this man had done, without having curiosity enough to find out what they were.

As an instance of the benefit of a scientific training, no matter to what branch of engineering the problem which confronts a man may belong, I may state that I have been assisted recently by a graduate of this School in trying to solve one of the problems that we have to face. A lumberman whose forest contained considerable quantities of hemlock (Abies Canadensis) was unable to harvest it profitably. There was no local market for hemlock bark, and this inability to sell the bark removed the profit there should otherwise have been in cutting the timber. I happened to know that Mr. J. A. DeCew, a graduate of the S. P. S., had been investigating the chemistry of woods, and I appealed to him in the matter. I have now in my office a very valuable paper prepared by him on the process of preparing extract of hemlock bark, or liquid tannin, and if moderate sized portable plants can be secured at a suitable price, hemlock lumber may be produced profitably in these limits, as is the case in similar forests near railways or near tanneries.

I mention this merely to show that the problems in forestry practice are either financial or scientific, or, correctly speaking, both. A college training, as I understand it, does not make a man a competent surveyor or engineer, but equips him so that he may become one. He may not have the expert knowledge required, but he knows, or should know, how to acquire it. He has been trained to apply his powers of observation, his "horse-sense," to the various scientific problems as they arise in actual practice.

Another problem in Ontario forestry, largely of an engineering nature, is presented in connection with the Temagami Forest Reserve. This reserve, comprising 1,400,000 acres of virgin forest land, contains a very large quantity of standing timber, some of which is mature and ready to cut. The territory is drained partly into the Ottawa River and partly through the Temagami and Sturgeon Rivers into Lake Nipissing, and thence to Georgian Bay. The height of land separating the two drainage basins is very narrow.

Before beginning to remove the mature timber from this Reserve, it will be necessary to know whether it would be practicable or profitable to connect the two systems of waterways. We will also require a more or less complete topographical map of the Reserve; will need to find out what improvements will be necessary to the various streams to enable the logs to reach the market, as well as to lay down and construct roads in the bush for hauling logs to the water. There are other problems of a purely sylvicultural nature, such as ascertaining the rate of growth and present age of the trees to be cut, in order that the cutting may be properly executed, problems to be solved by the expert forester; but many of the problems are of a purely engineering nature.

I have been frequently asked if I thought there was likely to be a chance of employment for scientific foresters in Ontario. I quite unhesitatingly say I do think so, not by the Government alone, but by lumbermen as well, for it will not be long before they will see, as the large forest owners of the United States already recognize, that scientifically trained men, who also have common sense, are better than men with common sense alone.

In this connection I have referred to some of the problems in Ontario to be solved, to show you that the training given in the School of Practical Science is quite in the line required for the special work when the proper time arrives. True, you will need special work in botany and practical forestry, but the instructions you are receiving in civil engineering, as I understand it, are such as you need for the forestry profession. Therefore, let me urge you when engaged in surveying, or in other branches of engineering, to observe conditions in the forest, in saw milling, in lumbering, and in all that pertains to this great industry. The knowledge you thus acquire will be useful, and you do not know how soon you may be called upon to put it to practical use.

THE USE OF IRON AND STEEL IN MINES.

D. L. H. Forbes, '02.

The increasing scarcity and cost of large timbers, together with their rapid deterioration in the air of most mines, are bringing masonry, iron and steel more and more into prominence as materials for mine structures which are intended to be of a permanent character. The use of iron and steel as substitutes for timber has already had a place for a considerable time in continental mining practice. They have also been employed in many English mines and collieries. In American mines, however, owing to the abundance and relative cheapness of timber in most mining camps, iron and steel have had but a limited use up to the present. But there is a tendency, even on this continent, to restrict the use of timber for many purposes in mining. This is partly due to the disastrous mine fires which often occur, and which cause mine managers to come to the conclusion that the extra cost involved in the use of non-combustible materials for lining permanent ways in large mines may frequently be justified. It will be the object of this paper to call attention to some typical constructions employing iron or steel which have been tried in mines and have been found satisfactory.

SHAFTS.

In lining shafts, rings of I-beams or channel-bars have been used extensively as curbs. They are upheld at the proper distances apart by struts of wood or iron, and backed by heavy planks or iron sheeting. The initial cost of iron lining in place is estimated to be twice that of wood and equal to that of masonry, but the cost of maintenance is only one-third that for wood and about the same as for masonry in dry shafts.*

The most successful methods of sinking shafts in running ground all employ iron tubing. The ordinary methods, as well as

* Ihlseng, "Manual of Mining," p. 337.

those of Triger, Haase, Kind and Chaudron, are described fully in the textbooks on mining, so that to mention them in connection with this subject will be sufficient.

Steel has recently been used in the form of expanded metal in lining the shaft of a Pennsylvania coal mine.* The No. 2 shaft of the Manville mine at Scranton had been lined with a double wood cribbing with clay between the cribs. Quicksand and water had caused this work to fail, and the management put in its place slabs of concrete 18 inches thick, reinforced by expanded metal. This construction is said to be satisfactory in keeping back the quicksand and water.

TUNNELS, DRIFTS, ETC.

In linings for tunnels, iron and steel have been used quite extensively in Europe, and various forms of construction are employed.

In the Halkyn Drainage Tunnel, Flintshire, where the sides are firm, but the roof weak, frames are employed consisting of two hollow cast-iron cylinders as posts with a 50-lb. rail strung across their tops. The head of the rail is placed downwards and rests in grooved chairs which fit into the tops of the cylinders. These frames are placed about three feet apart and planks or light rails are laid from one to the other. The space between them and the roof is tightly packed with stones. A dry stone wall is built upon each side with an occasional plank or rail to make it firmer. It was estimated that to have secured this part of the tunnel with good masonry would have cost nearly twice as much as this method, using iron, the cost of which was $10.75 (£2 4s.) per linear yard of tunnel.†

In France, special forms of I-steel are manufactured for frames in tunnels, levels, etc. A favourite form consists of two side pieces suitably bent at the top and united by fish-plates and bolts so as to form a shape like an inverted U. Another French frame much in use is composed of two semicircles of mild steel. For this, two kinds of sections are employed,—channel steel, and bulb tee steel.

* "The Doings of Expanded Metal," December, 1901, published by the Associated Expanded Metal Companies.

† C. Le Neve Foster, "Ore and Stone Mining," p. 259.

The channel steel used weighs about 16 lbs. to the yard. It is sawn into proper lengths on leaving the rolls and bent into semicircles while still hot. The two pieces are joined by sleeves of sheet steel fastened by a couple of iron wedges. Steel of the bulb tee section weighing about 26 lbs. per yard is employed for heavier ground.

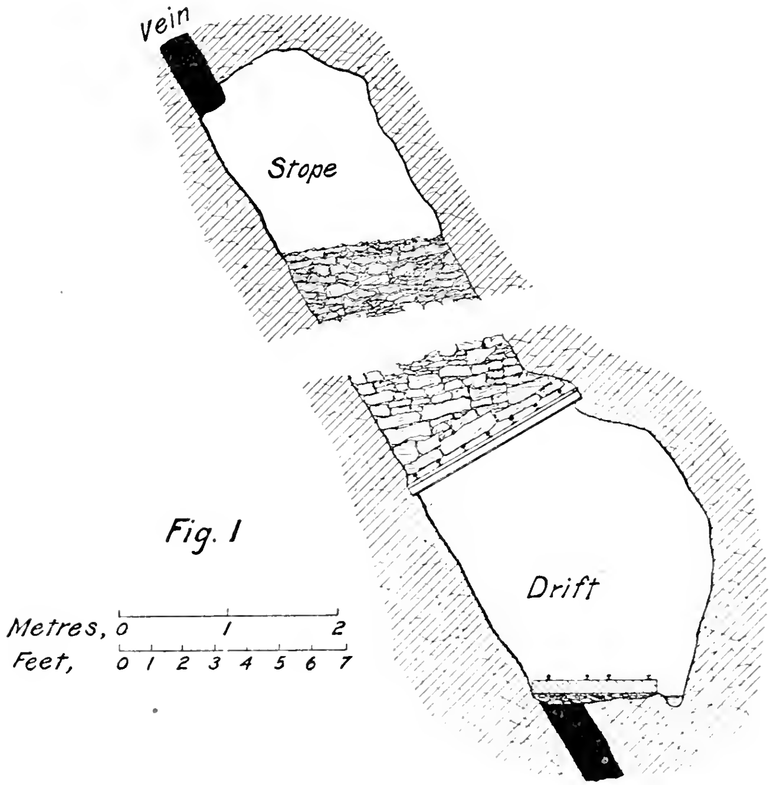


Fig. 1

While in Saxony last year, the writer was much impressed by the extensive use to which old rails are put in the silver-lead mines of the Freiberg district. Here it is claimed that, although iron costs about the same as masonry and will not last so long, yet, in setting up, the iron takes much less time and when completed occupies less space than masonry; while, in all probability, the iron will stand for

several generations.* In the Rothshönberg tunnel two rails are bent so as to form an elliptical shape, and united at top and bottom by fish plates and bolts. Behind these frames light mine rails are strung and flat pieces of rock packed in tightly all around. At other places in the district rails are used as posts and caps. The head of the rail used as cap is let into the upper ends of the upright rails. The feet of the uprights rest directly on the floor of the tunnel. Where the sides are firm and only the roof needs support, as in drifts where overhand stoping is employed, rails are placed across with their ends resting in hitches cut into the wall-rock, thus forming stulls to support the waste material heaped above. The rails used for this purpose are of varying size and cross-section, depending upon the load they have to support. Light mine rails are strung across these rails and spaced 6 to 8 inches apart, with flat pieces of rock laid on top to form the staging on which the miners stand and pile up the waste after each blast. (See Fig. 1.) In some of the Freiberg mines the rails are given a slight bend upwards so as to bring the principle of the arch into play. Where this is done, it is usual to give a bend of about 5 cm. in 100 cm. of length. It is claimed that the strength is increased by doing this, so that much lighter rails may be used than if they were straight under the same load. In places where the mine waters are acid, the use of iron for supports should be avoided. At several places in the upper levels of the Himmelfahrt mine at Freiberg, the rails have to be replaced frequently on account of the rapid corrosion caused by such mine water. Even coating the rails with tar is said to have but little effect in delaying the corrosion.

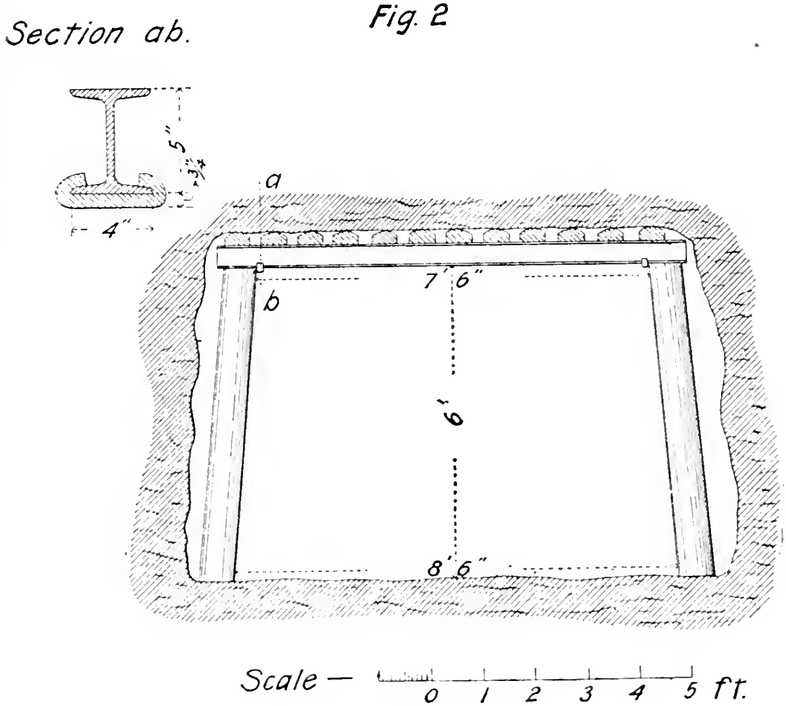
GANGWAYS, ETC., IN COAL MINES.

Steel I-beams have been used with success for some years at the Nunnery Colliery, Sheffield. The usual size is 4 inches wide, 5 inches deep, with 3-8 in. web. They are used either as caps on timber posts (see Fig. 2) or as posts and caps. In both cases the beam used for the cap has a lug or band of wrought iron, 1 in. x 3-4 in., shrunk on about a foot from each end. This prevents the posts from coming in sideways. Such frames or sets are placed 3

* "Freiberg Berg-und Hüttenwesen," pp. 176-183.

feet apart, and old timber is placed across from cap to cap, supporting the roof. The steel beams are tarred over with unboiled gas tar, and have been in use several years without showing any signs of deterioration; while timber at the same colliery lasts only two years on an average.*

Fig. 2



In another English colliery I-beams are similarly employed. As an experiment in this colliery, lengths of roads were timbered alternately with wood and steel (timber being used for props in both cases.) But, before definite results could be obtained, the district fired was dammed off and abandoned. After a lapse of 9 months, the roads were re-opened, and it was found that the steel bars had

* C. Le Neve Foster, "Ore and Stone Mining," p. 261.

suffered scarcely at all, only a few being displaced owing to their timber supports breaking. But, at places where timber caps had been set, the roof had fallen in, and considerable expense in wages was involved in repairing it. On a main haulage road in this same colliery 12-ft. girders of a section 6 in. x $4\frac{1}{2}$ in. with $\frac{1}{2}$-in. web, weighing 78 lbs. to the yard, were employed, replacing 9-in. timber bars. The first cost of the steel here was $2\frac{1}{3}$ times that of wood. The date of fixing each girder was noted, and in many instances the girders outlasted 3 to 4 sets of timber before removal; so that, even if the steel bars were worthless on removal, their actual cost would have been less than for timber. But, after being taken out, they had merely to be straightened and then were practically as good as new.*

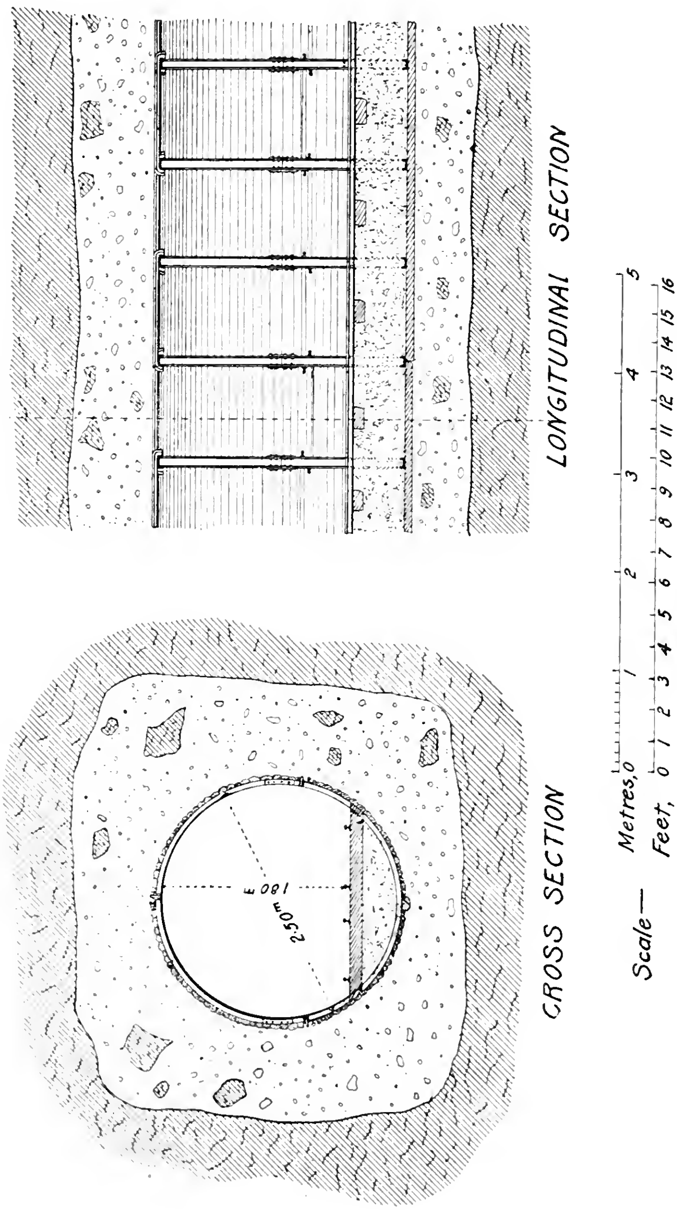
Cast iron cylinders are being used in place of timber posts in many English collieries. It has been said, however, that they are liable to break if any great side pressure comes on them. The Balmer prop is a modification which consists of two cast iron cylinders, of which the lower is filled with loose packing, and the upper telescopes into it as far as the packing will permit. Holes in the side of the lower cylinder allow some of the packing to be removed, so that the prop can shorten itself.†

For withstanding very great pressures coming from floor and sides as well as roof, two forms of construction which were observed by the writer in the Oberhohndorf colliery at Zwickau, Saxony, have been in use for several years. One of these is a tubular form, the frames being rings composed of two semicircles of channel steel joined by fish plates bolted on the outsides of the flanges (Fig. 3). The rings are $2\frac{1}{2}$ metres in outside diameter, and are placed 1 metre apart, centre to centre, each being held in position by three tie-rods or dogs joining it to the preceding ring. These tie-rods are made from mine rails cut to proper lengths and turned over at the ends The gangway to be lined with this construction has first to be enlarged until its cross-section is about 14 feet square, the roof and sides being held temporarily by timber props and logging. The excavation is carried about 20 feet in advance of the work of lining. The floor is first covered with concrete up to a certain level. A

* Hughes, "Textbook of Coal Mining," p. 137.

† Journal of Iron and Steel Inst., 1900, II, p. 472.

Fig. 3


LONGITUDINAL SECTION
CROSS SECTION
1.80m
2.50m
Scale—
Metres, 0 1 2 3 4 5
Feet, 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

timber sleeper 4 metres long is then laid on the concrete, given its proper leveling and alingment, and then firmly embedded with more concrete. Four of the channel steel rings are then set up and held temporarily by timber props and wedges. Timber slabs from 2 to 3 inches thick and 2 metres long are then placed in position on the outside of the rings, and concrete rammed in firmly all around. Temporary timber supports, which interfere with the work as it is built up, are cut away, leaving the lower parts imbedded in the concrete. When the concrete filling is about two-thirds of the height of the excavation it has to be continued in sections of one metre, the end face of the section being held with boards until it has reached the roof and has set. In a double-tracked gangway this work may go on without seriously disturbing its traffic, by keeping one track constantly supported and having a switch at each end of the place of construction, so that both in and out going trams may use it. The other track is used for hauling concrete to the work. Six men are required—two miners, two masons, and two shovellers. Working two ten-hour shifts per day, a section 4 metres in length is completed in six days. The total cost is about $50 per metre length of gangway. For single-tracked gangways a construction differing only in the employment of elliptical channel frames is used, but where the side pressure is very great, these frames have occasionally been crushed in at the joints.

The other form of iron construction used in the Oberhohndorf colliery is shown by the sketches in Fig. 4. Cross-rails used as sills are imbedded in a concrete foundation, and side walls resting on them are built up to a height of about 1½ metres above the floor of the gangway with a thickness of 1 metre. These side walls are constructed of layers of rail lengths laid crosswise and lengthwise alternately. Tie-rods prevent the rails from spreading, and concrete is packed in between and behind them. The roof is formed by lengths of rails, bent slightly at the middle, which arch against an I-beam at the top of the gangway and spring from a rail and angle-iron laid along the tops of the sidewalls. In between the webs of these roof-rails common sized bricks are placed. Concrete is rammed in tightly above the bent rails and the side walls. This construction was first put in about 16 years ago after a fire had caused the collapse of some of the main haulage ways and had necessitated the closing of one of the

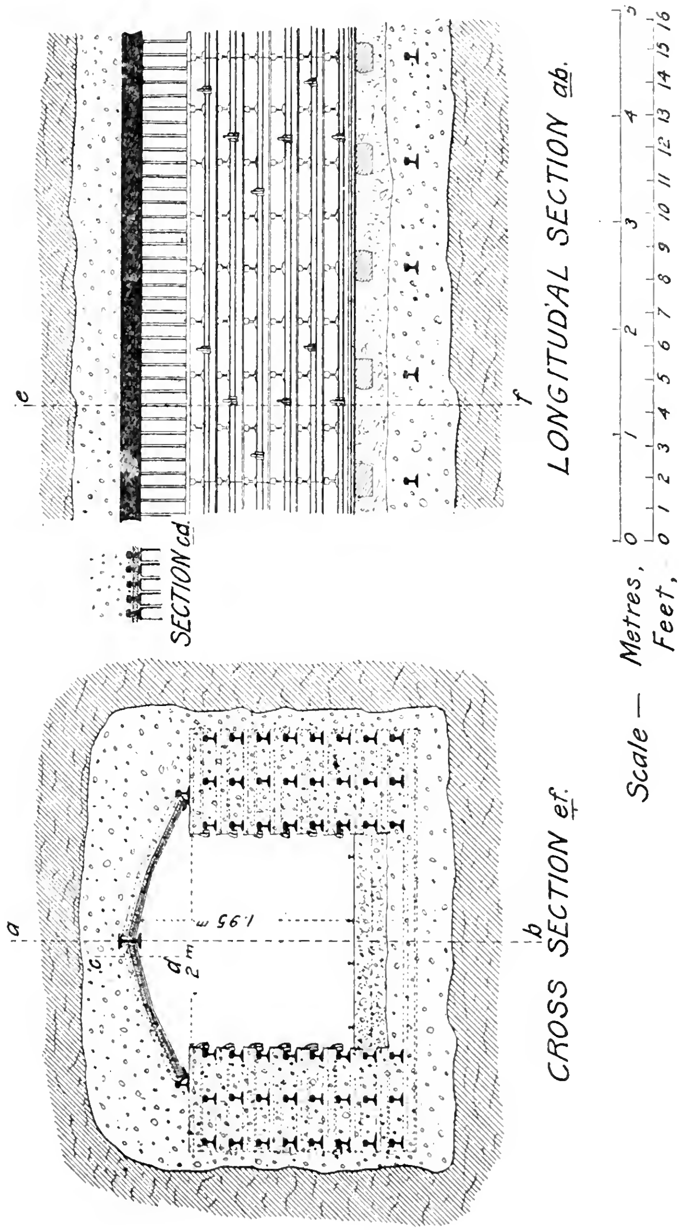

LONGITUDINAL SECTION ab.
SECTION cd.
CROSS SECTION ef.
1.95 m
2 m
Scale — Metres, 0 1 2 3 4 5
Feet, 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

Fig. 4

shafts for several months. The work of this kind which was then constructed is still apparently as firm as ever. Only the main gangways are supported in this way, and they only for a hundred metres or so from the shaft, on account of the expense, the cost being about $85 per metre.

At the Spring Valley coal mines, in Illinois, a new shaft had to be sunk in 1896, on account of a fire which had caused considerable damage. When the gangways and sidings were being constructed at the new shaft, the manager was particularly anxious to use as little timber or other combustible material as possible. The side walls were built of masonry and 15-in. I-beams, weighing 50 lbs. per foot, were placed 4 feet apart to support the roof. These I-beams rested on heavy cap stones in the tops of the walls. The width of the gangway is 14 feet, and its height 7 feet, from top of tracks to bottom of I-beams. The covering of the I-beams is composed of 3-in. oak planks.*

A similar use of steel girders is made in some of the Pennsylvania coal mines.

ADVANTAGES IN THE USE OF IRON OR STEEL.

The great advantage of steel beams over timber ones is in the matter of durability, which means a reduction in the cost of repairs. Besides this, however, there is the possibility of using the beams elsewhere when taken out. When only slightly bent they can be reversed and used over again. If badly bent they can be straightened or sent to the steel works to be worked over. In any case the steel has some value, but timber after failure is crushed and splintered so badly that it is worthless. Another advantage in the use of steel beams is the increased space for ventilation, due to the small size of steel beams compared with timber ones. Decaying timber takes fire very easily, and is moreover an important factor in causing the air of a mine to become foul. Finally, in setting up almost any form of steel or iron construction, the parts can be put together and the structure completed in less time and with less labour than masonry, or even timber used for the same purpose.

* "Improvements at the Spring Valley Mines," Trans. Am. Inst. M. E., vol. xxix, 1900, pp. 187-209.

BACTERIAL METHOD OF SEWAGE DISPOSAL.

Charles H. Rust, C.E., M. Can. Soc. C. E.

The following short account of the biological or bacterial method of sewage disposal has been prepared by the writer with the hope that it may be of some interest to the members of your Society.

It is only within the past five or six years that the bacterial method of disposal has been brought prominently before the public, but there is now a large number of small towns in England that have adopted it, and some of the largest cities have been experimenting, with a view of doing so, while in America at the present time several towns have installed sewage works upon the bacterial system.

The following short extract will explain clearly what bacteria are:—"Bacteria are minute forms of vegetable life, whose existence was not even suspected until late in the seventeenth century. They are so small that it requires the most powerful microscope to make them visible at all. There are other low forms of life which bear a part with them. They may be divided into two classes, the anaerobic and the aerobic. The anaerobic live without air, that is without free oxygen, the aerobic existing with free oxygen. Exposure to air kills the anaerobes, and all bacteria are destroyed if allowed to remain too long in contact with their own products. In the absence of water, or at least moisture, they are unable to multiply and remain dormant. The work bacteria do in the purification of sewage is to oxidize the foul matters of which it is partly composed. To effect a thorough purification three separate processes are needed, viz. (first) anaerobic, (second) partly anaerobic and partly aerobic, (third) aerobic."

The subject may be discussed under two heads, first, the so-called septic tank; second, the contact or bacteria beds; and under this heading comes land treatment, either by broad irrigation or by intermittent downward filtration.

The septic tank consists of a tank or series of tanks, and was first introduced by Mr. Cameron, City Surveyor of Exeter, in 1895, when a small experimental one was installed to dispose of the sewage of Belle Isle, Exeter. These tanks when first introduced were covered, but now this is not considered absolutely necessary, although the writer is of the opinion that in this country, on account of the climate, it would be more satisfactory during the winter months to have some form of cover. This system altogether changed the old methods of treating sewage, when all suspended solids were thrown down by means of chemicals. In a septic tank the solids are liquefied by means of anaerobic bacteria. "It used to be considered necessary to prevent decomposition, but in the septic tank the object is to promote it. It was also considered necessary to exterminate all the bacteria. Now they are cultivated."

The action that takes place in the tank is a process of removing most of the suspended organic matter, some which is in solution, giving an effluent, which, although not chemically pure, is inoffensive, and in some cases pure enough to be turned into large streams or bodies of water without creating a nuisance. This is all brought about by the action of anaerobic bacteria, which are different from those which act in the contact beds, and in land treatment. They thrive in the absence of oxygen and are the organisms which cause putrefaction.

Instead of filling and emptying the tank alternately, as is done in the chemical process of precipitation, the sewage runs continuously through it, the motion being so slow that the contents are practically at rest. This affords an opportunity for the separation of the solid matter, the heavier substances falling to the bottom while the lighter ones rise to the surface. This results in a thick scum forming on the top of the liquid. Bacteria are thus afforded conditions very favourable to their growth. The bottom of the tank is covered with a deposit largely mineral, but is very small compared with the amount of solid matter that comes in with the sewage. It is necessary, especially where the combined system is in use, before putting the sewage into the tanks, to pass it through grit chambers, which should be cleaned out at frequent intervals, and it would be advisable also to have screens in front of these chambers, for the purpose of intercepting bits of wood, rags, etc. These chambers

should be frequently cleaned out and the sludge burnt, if possible. Having first removed these insoluble substances from the sewage, it will be much easier to obtain a higher percentage of destruction in the tanks.

The capacity of the tanks will vary somewhat, depending upon the condition of the sewage. In England it has been the practice to provide a capacity in the tanks equal to three-quarters to one and one-half day's supply of sewage. In this country, owing to the much weaker nature of the sewage, one-half to three-quarters of a day's supply will probably prove sufficient, although the writer understands from the result of the recent experiments made at Manchester that a system of septic tanks having a capacity equal to one-half the daily flow of sewage will be ample.

After the sewage passes through the grit chambers, it flows into the septic tank, where it is acted upon by the bacteria. It is found in the septic tank that the action begins slowly and gradually rises up to the maximum. It is, therefore, important that the ultimate flow should not be passed through the tanks at first. If this were done sludge would rapidly accumulate before septic action commenced.

The great advantage of the septic tank over the old system of precipitation by chemical means is the large reduction in the amount of sludge produced. Not only does a reduction in the amount of sludge take place, but the tank is of great use in obtaining an effluent for after treatment on contact beds, and it also produces an effluent readily capable of nitrification.

At Exeter, where there is a small experimental tank which has been in use for the past six years, enough gas is produced for lighting the works and for running a small gas engine. It is, however, questionable whether the amount of gas given off in an open septic tank would be of sufficient value to pay for the cost of collection, but in the new plant now being constructed for treating all of the sewage of Exeter, the tanks are to be covered and it is proposed to obtain a sufficient quantity of gas to illuminate and provide power for the extensive works. It is, however, not supposed that there will be a sufficient quantity of gas to do this until a period of some months has elapsed. The gas which is given off as the result of decomposition is marsh gas and free hydrogen.

This description of the septic tanks, although short, will probably explain clearly to the members of your society their working.

The contact system consists in passing the sewage into beds filled with from three feet to four feet of filtering material, usually clinkers. These beds are open and in them the sewage is acted upon by aerobic bacteria, which thrive in the presence of air and light, and the greater portion of the organic matter is removed or changed into harmless compounds. If a higher degree of purification is required, the effluent is passed from the first into another and finer bed. It is absolutely necessary, in order to secure a good effluent, to have these beds thoroughly drained and aerated, for if the water cannot get out the air cannot get in, and the lower part of the beds gradually becomes putrid. These beds are drained in some cases by ordinary drain pipes and also by agricultural drains, 3 to 2½ inches in diameter, the rows being 2 feet apart.

When this system was first introduced it was generally supposed that coke would make a satisfactory filtering mterial, but that has not been found to be the case, the sewage having a tendency to gradually break down the coke, and as it was necessary to use a more refractory material, clinkers were adopted. In addition to clinkers, coarse gravel or broken stone would be a satisfactory material, and the writer has heard of broken glass being used with satisfactory results. The beds in the majority of cases are constructed of either brick or concrete, although in a few instances where the soil has been suitable, they have been constructed without masonry. There is not sufficient information available at present to know definitely the lifetime of the filtering material or the annual cost of operation. In spite of all precautions it may be necessary, after a period of three or four years, to either replace the material or have it washed. Up to the present time, from the result of the experiments made in the various cities and towns in England, it has been found that the capacity of these beds has decreased 33 per cent. shortly after being installed, but have since shown no further signs of decrease. "The beds must also be worked very slowly at first in order to allow the material to settle and the bacterial growths to form. In this way there would be less danger of suspended matter finding its way into the body of the bed while the material is still loose and open." The beds become choked by reason of the settling together

and breaking down of the material, imperfect drainage, insoluble matter entering the beds, and the growth of organisms. The defective drainage decreases the actual water capacity of the beds and prevents thorough aeration, and other means should be taken, therefore, to make it as perfect as possible.

The manner of putting on the sewage to the beds is generally as follows:

Each bed is filled three times per day, the filling generally taking about three hours, while the time taken to empty is from 1½ to 2 hours, and the beds in some cases are allowed one week's rest in five, and in other cases they are given 7 hours' rest. The flow of sewage is in some cases controlled by an alternating gear and in other cases by the Adams syphon or by manual labour. "The alternating gear automatically opens and closes the various valves in their proper order and at regular intervals, and the supply and discharge valves for each pair of filters are suspended from the outside ends of two levers, which are connected to one shaft. This shaft carried a couple of rubber actuating buckets, which furnish the motive power. As soon as the filter is filled a small quantity of the liquid overflows from its discharge well into one of the actuating buckets belonging to another pair of filters." This action goes on so that each filter is in turn filled, rested full, discharged and aerated.

In addition to the treatment by the ordinary Dibden contact bed, experiments have been made with continuous filters, such as the Whittaker and Bryant, and Stoddart. The patentees for these filters claim that as much as 3,000,000 to 8,000,000 gallons of sewage per acre per day can be treated.

The following is a description of the Whittaker and Bryant filter in use at Rochdale, England, kindly furnished me by Mr. Pratt, Borough Surveyor:—

"There are two filters, each having a surface area of 200 square yards=400 square yards. The volume of sedimented sewage treated thereon is about 160,000 gallons per day of 24 hours. The sewage is continuously applied. Each filter is constructed as follows:—The foundation is of cement concrete rendered to a smooth surface and made to fall towards a channel on one side provided for the collection of the effluent. Resting on the concrete are two courses of

bricks in rows supporting 18-in. perforated half pipes, above which is the filtering material, 9 feet in depth, composed of gas coke which has had all smaller than 1½-in. taken out of it.

"In the centre of each filter is a perforated chamber or shaft of brickwork, pigeon-holed for aeration of the filtering material, on the top of which rests the mechanism for distributing the sewage. This mechanism consists of four revolving arms 1¼-in. and 1-in. iron pipes, which are perforated at varying distances and with holes of varying sizes, so as to ensure a uniform distribution of the sewage over the whole of the upper surface of the filter. The sewage dealt with is not treated at all by chemicals, but passes into an open septic tank, of capacity about 200,000 gallons, or rather more than the daily volume treated. This tank has been in continuous operation since July, 1899, and the sediment accumulated is now about 12 in. deep. From this open septic tank the effluent is syphoned into a small collecting tank of about 750 gallons capacity, placed near the filters, and from this it is pumped by a No. 5 pulsometer pump, which lifts the tank effluent and forces it to the distributors of both filters, and causes the arms to revolve at the necessary rate to ensure the uniform distribution over the upper surface of the filter. The steam used in the pulsometer passes into the sewage, and in addition to that a jet of steam is injected into the sewage (in winter) on its way to the revolving arms, in order that the temperature of the distributed sewage shall be as nearly as possible about 10 deg. F. higher than that of the sewage in the open septic tank, so as to ensure the better bacterial action of the filter.

"The effluent from the bacterial beds contains a certain amount of suspended matter, and with a view of removing this as far as possible it is passed through a settling or deposition tank of about 10,000 gallons capacity.

"The settling tank requires to be emptied twice a week, the effluent and the precipitated matter which cannot be drained away being pumped back into the open septic tank."

The results of experiments made in England with this class of filter are, I believe, fairly satisfactory, and Accrington has adopted these filters for the treatment of all the sewage, but owing to our severe winter, I do not think the continuous filter would be a success in this country. The results so far show that the maintenance of the beds and septic tank will not be costly.

The members of your Society are probably aware that it is not absolutely necessary to have the septic tank followed by after-treatment on contact beds. In places where a high degree of purity is not required, septic tanks alone will be sufficient, or, as is the case in some small towns in England, contact beds with either two or three contacts, without the septic tank, would be satisfactory, but it would be advisable to first pass the sewage through small settling tanks.

Last winter the writer had an opportunity in England of inspecting some of the sewage disposal works, and below is given a description of the method in operation in four small towns, which have adopted, with very satisfactory results, the bacterial method of sewage disposal.

HAMPTON.

The plant at this town was one of the best and most complete the writer inspected. Owing to the rigid requirements of the Thames River Conservators, three contacts are used. The Local Government Board ordered the effluent to be discharged on land after coming from the contact beds, and the Council purchased 20 acres of land for this purpose, but it was found that the effluent actually deteriorated after land treatment, and consequently it was discontinued. The effluent is used for condensing, feeding and cooling purposes. The sewage is delivered at a screening chamber, where it passes through ½-in. screens, and thence to the beds without sedimentation. There are fifteen beds built in terraces of five each. The coarse or first contact beds are 4 ft. 4 in. deep, 50 ft. x 34 ft. 6 in. filled to within 4 in. of the top with coarse clinkers rejected by a 3-4 in. sieve. The medium or second contact beds are 54 ft. x 35 ft. 6 in., filled with clinkers rejected by a ¼-in. sieve. The fine or third contact beds are 58 ft. x 35 ft. 6 in., filled with residue from screened bed consisting of finely powdered clinkers and ashes. The beds have a fall of 6 in. and are drained by semi-circular pipes, 5 in. in diameter, formed of concrete. They are 2 ft. 6 in. apart and 6-in. sluice valves are used. The liquid capacity of the coarse beds is 20,000 gallons, or 46 per cent. of the total. This capacity has not been decreased since the beds were first used in 1898. There is a population of about 4,200 now connected with the sewers, and about 100,000 gallons of sewage is being treated daily.

The operation is as follows:—

A coarse bed is filled to within about 4 in. or 6 in. of the surface of the bed material, and allowed to stand full about two hours, then emptied slowly, taking about one hour. The same process is employed with other beds. The beds are allowed one week's rest in five. The coarse beds are charged by shallow bays 8 ft. or 10 ft. wide, running across the entire width of the bed, and sunk about 6 in. below the level, and are cleaned by skimming the surface and lightly turning it over, after a week's rest. On the medium beds the sewage is distributed by 12-in. half channel pipes, having 6-in. branches, 2 ft. 6 in. apart. The spaces for drainage at the bottom of the beds are filled with large clinkers. The surface of the medium beds requires no attention, but the surface of the fine beds requires occasional weeding. No particular method is adopted for distributing the sewage on the fine beds. Tomatoes are grown on the coarse beds.

SUTTON, SURREY.

This town was one of the first to adopt the bacterial treatment of sewage, and the beds have now been in use four years, with very satisfactory results. The population of Sutton is about 18,000, and the daily flow of sewage 550,000 gallons. The sewage was formerly precipitated with lime, and the precipitation tanks were converted into bacteria beds when the system was first introduced. These beds are 55 ft. x 35 ft. and 3 ft. 6 in. to 5 ft. deep. There are now seven coarse beds and five fine ones. All the new beds are built in clay, the coarse beds being 125 ft. x 45 ft. and 150 ft. x 135 ft., but the smaller size seems to be preferred. Fine beds are used for second contact and are 160 ft. x 30 ft. and 170 ft. x 30 ft. The filtering material has been used in some of the fine beds for four years, and they are only raked over in summer to prevent growth of weeds. The fine beds are ridged and furrowed, and the material used is coke breeze and burnt ballast. The effluent runs into a small creek and is very satisfactory. There are also a few small septic tanks which are covered with galvanized iron sheeting. The beds take 1½ to 2 hours to fill, care being taken to prevent the sewage from reaching the surface of the beds, the flow being stopped as soon as the level rises to within a few inches of the top.

In 1891 and 1893 the original works were constructed, and designed for chemical precipitation and broad irrigation, and until 1896 the whole of the sewage was treated by chemicals. The effluent, however, was not such as to satisfy the requirements of the conservators of the River Thames. There was also considerable difficulty in getting rid of the sludge, as there was no demand for it, and in 1896, at the suggestion of Mr. Dibdin, the eminent chemist, they constructed the first bacteria beds for the treatment of crude sewage in England.

Mr. Chambers Smith, borough surveyor, informed me that the bacterial treatment was much cheaper and more satisfactory than the old system of chemical precipitation.

EXETER.

The first septic tank installed in England was at Exeter, and was constructed by Mr. Cameron, city surveyor, in 1896. It is a small plant for the treatment of the sewage from the St. Leonard's district, the population being about 1,500, and the daily flow of sewage 90,000 gallons. The septic tank is 65 ft. long by 18 ft. wide and 7 ft. 6 in. deep. There are five filters, one being held in reserve. These have each an area of 80 square yards and a depth of 5 ft. Furnace clinker is used in four of the filters, and broken coke in the other. No attendance is required, the flow and discharge being controlled by an automatic arrangement. The material used in the construction of the tanks, etc., is concrete. The septic tank has not been cleaned since it was constructed; the effluent is very good. A new plant is now being constructed to treat the whole sewage, providing for a population of about 55,000. In the immediate vicinity of the works there are several residences, and the writer was informed that no complaints have been made.

BARRHEAD.

The population of Barrhead is 10,000, and the daily flow of sewage is from 350,000 to 400,000 gallons. The works in this town were constructed by the Exeter syndicate, and the septic tank and one contact is used. There are four septic tanks, 100 ft. x 18 ft. x 8 ft.; two settling tanks or grit chambers, 18 ft. x 6 ft. x 5 ft., and also eight contact beds, 54 ft. x 54 ft. x 4 ft. deep, the material used being clinkers. The beds are underdrained with

agricultural tile drains 3 in. to 2½ in. in diameter, placed 2 ft. apart, and the walls are composed entirely of concrete. The time occupied in filling the beds is 1½ hours. The same period is taken to empty the beds, and the sewage is allowed to stand 7 hours The cost of the works was $25,000. Alternating gear is used to control the flow and discharge from the pipes, and one man is employed. The effluent appeared very good, and, although there were two dairy farms in close proximity, there have been no complaints. The works have been in operation two years.

In addition to the above places, Manchester, Sheffield and Leeds have been conducting for some years past a series of very elaborate experiments, and Manchester is so satisfied with these that the city is now engaged in constructing works consisting of septic tanks and bacteria beds, for the treatment of all the sewage of the city.

The writer is especially indebted to Mr. Gilbert J. Fowler, Superintendent and Chemist in charge of the Manchester Corporation Sewage Works, for a great deal of the information contained in this paper.

Toronto, January 15th, 1902.

UNDERPINNING THE WEST WALL OF THE STOKES BUILDING, 49 CEDAR STREET, NEW YORK CITY.

T. Kennard Thomson, C.E., M. Am. Soc. C. E.

In February, 1900, the Mutual Life Assurance Company awarded a contract for the foundations of their new building on Cedar and Liberty streets to Arthur McMullen & Co. This contract involved making four stories below the street level and placing the cellar floor 35 feet below the water level, which, of course, necessitated supporting the adjacent walls, as the foundations of the new building were to be from 60 to 80 feet below the foundations of the adjoining walls, which were resting on quicksand near the surface of the standing water. Much of this was described and illustrated by the writer in the Engineering News of March 28th, 1901, but the underpinning of the Stokes Building was only slightly described in that publication. Owing to the fact that this wall was very badly constructed it caused a good deal of worry until it was safely underpinned. The New York Building Law, although full of many absurdities, is very explicit in one respect where it states that the owners of adjacent buildings must give the contractors free access to their property in order to protect the same from damage, or else take the responsibility of making their building secure themselves while the foundations for the new buildings alongside are being put in at a lower level. But in spite of this law the Stokes people caused a good deal of delay to us before giving us access to their property, with the result that it was the middle of June before work was started on this unique wall. It might be termed a combination wall, inasmuch as the Cedar street corner had no iron columns, but consisted of a good brick pier for the whole twelve stories. The northerly corner had a heavy cast iron column 24 x 28 inches, with 1 3-4 inch metal in the basement, first and second stories, above which was brick work alone. Between the two corners were three cast iron columns 16 x 15 inches, 1½ inch metal for the first five

floors with an 8 inch brick wall, and above the fifth floor was nothing but a 12 inch brick wall. The four columns rested on good granite caps supported by good brick piers, which were vertical on the outside of the Stokes wall, but stepped off on the other three sides, making a broad base, but eccentrically loaded. These granite caps had been very badly set and were all cracked through the middle when first loaded. In fact the entire wall seemed to be as flimsy and disconnected as possible, and before sinking any caissons for underpinning purposes it was absolutely necessary to bind the various parts together so that jacking against one portion of the building would not break it in two, and the only possible way to do this was by means of plate girders from one end of the building to the other. As the three centre columns rested eccentrically on the edge of their brick piers, it was not safe to undermine these piers to place the girders below the granite caps, nor was there room to place the girders between the bases and the street floor, and the only place left was just above this floor. It was therefore decided to use 6 feet deep plate girders, one on each side of the columns, with the bottom flange about the level of the ground floor. As it was not desirable to run this girder outside of the building line above the sidewalk, the plan of supporting the corner brick pier by independent girders 18 feet long was adopted, leaving 4 feet between the top of girder A and the bottom of girder B, girder B lapping over girder A about 3 feet, which permitted girders A and B being connected by a heavy column consisting of four 15 inch, 60 pound channels, 16 feet long. The girders A and B were each 15 inches back to back of web plates, which were drawn up close against the sides of the 15 x 16 inch columns. As the corner column was 24 inches wide, and not on the same centre line as the 15 inch columns, it was decided to splice the 6 foot girders about half way between the corner columns and the first 15 inch column, making an offset of 3 7-16 inches on the inside of the building and 5 3-4 inches on the outside, which was done by using 6 x 6 inch angles. (See Fig. 1.)

The corner column was so excessively large that all the holes we wanted to drill in it could not affect the safe strength, so 63 bolt holes for one inch bolts were drilled through the column and both girders without reinforcing the column in any way. But the owners of the Stokes building were afraid to trust the other three

columns unless they were reinforced, so four 6 x 6 x 5-8 inch angles 12 feet long were bolted on each side of these columns, having the bottom of the angles flush with the bottom of the girders and stand-

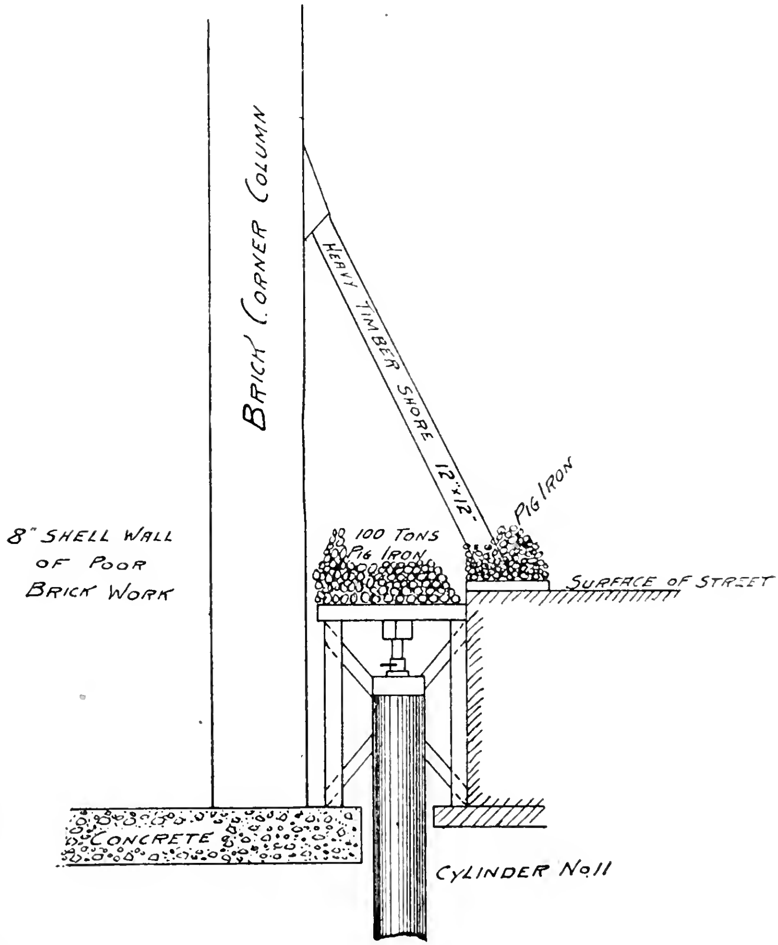


FIG. 1.

ing up 6 feet above the girders. Twenty-five 1 inch bolts connected each pair of these angles of the columns, leaving about three feet of blank angle above the top bolt; this was the only modification in our

plans made by the Stokes people and was made so as to permit clamping the four angles to the column, thus reinforcing the section before getting down to the bolt holes. Twenty-one short bolts connected each of these angles to the girders, which had in addition seventeen long bolts through both girders and column. These girders had 72 x 3-4 inch web plates, one 6 x 6 x 3-4 inch flange angle top and bottom throughout, with base plates where required. The flange angles were of course turned out. All long bolts were nominally 1 inch in diameter, having one end upset to 1 1-32 inch and the other end to 1 3-64 inch for a length of 2½ inches, the middle of the bar remaining one inch in diameter, the screw for the nut end being slightly smaller to prevent injury in driving. This design of bolt permitted tight driving through both girders and both sides of the column. The 12 foot angles were made in pairs with one angle punched in the shop and the other left blank, so that when one was in place the holes were drilled clear through the column, then its mate was put in place and the holes centre punched, the angle was then taken down and drilled, after which the pair of angles were put in position and the holes reamed out. These bolts were driven just as hard as it was considered safe to drive without running a risk of splitting the columns with a line of bolts as wedges. This operation would have been tedious, the bolts going through the girders and column, so a frame was rigged up to permit drilling the holes from each side of the column, which, of course, did not give holes in absolutely true line through both sides of the column and girder, but it was found that all that was necessary was to shove a bolt through from one side and see how far the hole on the other side of the column was off centre, and then give the bolt a slight tap on a log of wood, and with a little practice the men were able to bend the bolts to the exact amount required. Each bolt was put in a lathe, pneumatic, and each end was filed down until both ends of the bolt had a good hard driving fit for its hole.

The first intention was to sink heavy cylinders between the columns of the old building and carry the old columns entirely on the girders, but when the Stokes people raised objections to leaving the girders in permanently, claiming that because the top flange would extend 4 inches into their room and decrease the rental value thereof, it was resolved to put down the caissons between the col-

umns first and carry the columns by means of these caissons and the girders, and then undermine the columns themselves by new or additional caissons, which of course would take the strain off of the girders and intermediate cylinders. Before any work was done on the building a partition was placed about 3 feet from the wall on the inside of the Stokes building, so that the tenants would not be disturbed in any way by the operations on the wall. This partition was made of boards and studs with 4 inch terra cotta blocks behind, and was then papered. Coming to an understanding with the Stokes people, and putting in the partition and girders B and C took time, so that it was July 21st before any caissons could be put directly under the wall. In the meantime, however, a trestle had been built at the north end of the wall, to hold 100 tons of pig iron to resist the jacks used to enforce cylinder No. 9 down, as this cylinder came entirely beyond the building and formed half of the temporary support for the end column, for although this cylinder was directly under the end of girder C, it was not considered safe to jack against the girder for fear of putting bending strains in the end column, which as already stated, was of cast iron, and ran up only two stories. Cylinder No. 9, the first eight being under another wall, was jacked down to rock under this platform through 36 feet of quicksand, 12 feet of hardpan, and then through 9 feet of fine sand and decomposed mica. The jacking started on July 9th, and the cylinder was filled with concrete on July 20th, or in 11 working days. As this caisson was intended to be used only until the new cellar was completed, a temporary support was quickly made to go between the cylinder and girder C, by taking four 20 inch I-beams, weighing 65 pounds per foot, and 10 feet 7 3-8 inches long, and bolting them together in pairs with two 8 x 10 inch timbers for separators. Under and also over this post were four 15 inch I-beams weighing 60 pounds per foot and 3 feet long, to distribute the strain from the girders above and to the cylinder below. Between the post and the upper I-beams were two 8 x 1½ x 20 inch plates over each of the four vertical beams, with four steel wedges the same size as used on the previous cylinders, each wedge being 2½ inches wide, ½ inch thick at one end, and 1 inch at the other end, and 18 inches long, and of course planed on top and bottom. These 16 wedges were driven until the girders were slightly deflected upwards. The pig iron was then transferred to a similar trestle built under the curb to jack

down cylindrical caisson No. 11, which was started on July 21st and finished August 9th. By this time the Stokes people had decided that our girders B and C would have to be removed before we left the job; so it was resolved to stop three cylinders that did not come directly under any old column near the top of the hardpan instead of carrying them to rock like the other seven. This kicking by their neighbours however saved the Mutual Life Company quite a little expense and time; for instance, cylinder No. 10, which was started the same day as No. 11, was completed on August 26th, or in six working days, as against ten, No. 11 being delayed a couple of days waiting for cast iron cylinders, although we had two different shops at work on these cylinders since early in April.

The cylinders were the same as those used under the Mutual Life Building on Cedar street, being 3 feet outside diameter and 33 inches inside diameter. The details of these cylinders, with their steel cutting edge, diaphragm caps, etc., are fully described in the Engineering News of March 28th, 1901. Cylinder No. 9, however, had three diaphragms, 4 feet, 9 feet, and 19 feet from the cutting edge, as there was not sufficient head room to jack down 9 ft. of cylinder before striking water and necessitating the use of compresed air. Cylinder No. 10 went through 40 feet of quicksand and 3½ feet into the hardpan to get a good bearing. Cylinder No. 11 passed through 35 feet of quicksand, 13 feet 4 inches of hardpan and 7 feet of fine material under the hardpan, landing on bed rock. Cylinder No. 12, commencing on July 31st, sank through 35 feet of quicksand and 2 feet 7 inches of hardpan, being concreted on August 4th and 5th. Cylinder No. 13 penetrated 32 feet of quicksand and 3 feet 4 inches of hardpan, taking from August 7th to August 15th. Cylinder No. 10 had five 15 inch at 60 pound I-beams 3 feet 6 inches long on top of the cap, and four vertical beams, the same as for the first eight cylinders, under the opposite wall, but these were wedged directly under the webs of the girders. On cylinders Nos. 12 and 13, the distance from the cap to the girders being shorter, the horizontal beams were omitted.

The entire wall, with the exception of the Cedar Street corner, now being carried by the girders B and C, it was safe to commence undermining the four cast-iron columns. The brick piers and 3½ feet of concrete were very hard and slow to remove, even with the

aid of a gadder drill, so that it was August 22nd before the sinking of cylinder No. 14 commenced, where the material was found to be 32 feet of quicksand, 15 feet of hardpan, and then $10\frac{1}{2}$ feet of fine sand and boulders. This cylinder was completed on September 5th. Five 15 inch 60 pound beams were placed under the granite caps, and the wedges driven between the beams and the cast iron cap

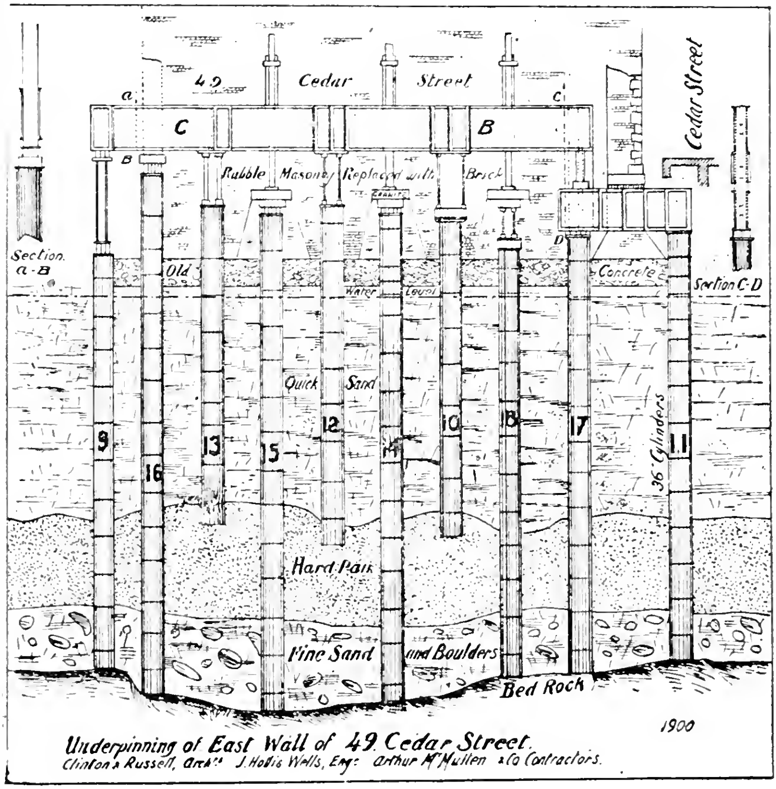


FIG. 2.

until the column and granite cap above were lifted a hair's width. Cylinder No. 15, commencing on August 26th, passed through 30 feet of quicksand, 17 feet of hardpan, and 12 feet of fine material under the hardpan, and was filled on September 4th; the wedging, etc., being similar to No. 14. Cylinder No. 16 is directly under the corner column, and while the shoe and bottom section of the

old column were being removed, thus transferring the entire weight of this corner of the building from the old base to the new girders, a Y level was kept sighted on the girders from a secure position on the opposite side of Liberty Street, and at no time did the weight of the building cause the slightest deflection in these girders, C, showing that the wedging had been sufficient to overcome any tendency to deflect. Cylinder No. 17, which supports one end of girders A and B, and consequently is half the support for the Cedar Street corner brick column, was held back until September 8th, until access could be had to the place, and was landed on rock on September 25th, the hardpan being 14 feet thick and 9 feet above the rock.

As soon as No. 17 was filled and capped, girders A were put in place. The erection of these two girders caused more worry and anxiety than any other part of the work, for this corner consisted of a brick pier, or rather column, 5 feet x 6 feet and twelve stories high, and to cut a notch in one side of this column near the bottom 7 feet high, and about 20 inches into the pier, or, in other words, cutting off about 20 inches out of 60 inches to place the girders A in, was cutting a big slice. Before making this cut four 12 x 12 inch inclined shores of timber were placed side by side, with their tops braced against the floor of the second story and the bottoms firmly secured about the level of Cedar Street. (See Fig. 2.) A similar strut of four timbers was placed on the lot side of the corner. Then seven inches of the 20 inches were stripped off the side of the brick column and three 15 inch beams 6 feet 6 inches long and weighing 60 pounds were put in place and wedged up while the remaining 13 inches were being cut out, and when this was done two of the beams were removed and the inside girder A was put in place and temporarily wedged up, when the third strut was removed and the outside girder A was quickly slid in place and levelled up, and then the two base plates and the cover plates were quickly bolted up. One fact which relieved a good deal of anxiety about this corner, was the fact that a few inches above the girder was a good granite cap 18 inches thick, extending under the whole corner, which greatly reduced the risk of the brick work above cracking. As the vertical space to this cap was only 6 3-8 inches, it was decided to use fifteen 4 inch rails weighing 60 pounds per yard, cut in 2 foot lengths and placed side by side. A filler 3 inches x 5-8 inch x 5 feet was placed

over each web so that the rails would not foul the heads of the cover plate bolts. The rails were of course placed at right angles to the girders, and over each rail were driven two pairs of wedges, the upper wedge bearing directly against the 18 inch granite cap. Each wedge was 2½ inches wide x 12 inches long x 7-8 inch thick at one end and 1-8 inch at the other. An assortment of shims 1-16, 1-8 and 1-4 inch thick, were used for evening up. The wedges were driven hard, and then all the interstices between the rails were filled up and the most treacherous part of the underpinning was completed. The next operation was the connection of girders A and B, which was designed to carry either tension or compression: tension when the jacks were being used on cylinder No. 18, to avoid any danger of bending the super-imposed old column, and compression to carry the same column when the jacks had been removed. Both girders were placed 15 inches back to back of web plates, and the strut was made by bolting four 15 inch channels 16 feet long to the webs of girders A and B, the channels being coupled by several 12 inch tie plates. The girders proved rigid enough to withstand the application of two 125 ton jacks without deflection.

The entire western wall of the Stokes building being now secured, the last cylinder, No. 18, was sunk to support the column after the girders should be removed. This cylinder was started on October 13th and completed 11 days later. There we had 10 feet of fine stuff under 10 feet of hardpan and 35 feet of quicksand on top. The entire wall was thus wedged off its original supports. One cause of worry was the poor connections of the old iron work; for instance, the floor at one place was carried to the column by two 20 inch I beams; but the only connections between the beams and the column were two 3-4 inch bolts for each beam. It is true that brackets had been placed on the columns under the beams, but through some mistake in the shop they were placed 3-4 of an inch too low to do any good. Several months after the work on this wall was completed. these 3-4 inch bolts were sheared off, allowing the 20 inch beams to drop on the shelf brackets. It is probable that as the ends of these girders were exposed to the winter weather, that the expansion and contraction had snapped the already overstrained bolts. When all the joints exposed to view showed such a bad state of affairs, it left considerable doubt as to what the remaining joints in the building were like, and therefore it was not considered advisable to remove

the girders B and C until the iron work of the new building was erected. It would of course have been vastly better to have left both girders in permanently, but the Stokes people demanded $10,000 if the inside girder was left in, although they would have had a much safer building at no cost to themselves. Eventually we removed the cover-plates and flange angles of the inside girder, leaving both web plates in place.

In this building, as before, when the concrete was put in the air chamber to the level of the lower door when hanging open, the air was left on for twenty-four hours with a gaugeman to watch the indicator, but one Sunday night the man must have went to sleep and allowed the air pressure to increase probably to the pressure in the receiver, about 40 pounds per square inch, instead of keeping it down to about 20 pounds. The result was that the air forced its way through the 6 feet of hard concrete, bubbled up around the cylinder and raised the surrounding sand a foot, allowing two feet of sand to flow over into the cylinder. This and several other incidents proved the utter unreliability of labouring men for gaugemen. Four hydraulic jacks were used on this job, two of 60 tons capacity and two of 125 tons each. These jacks required a good deal of repairing. Sometimes one jack was used on a cylinder and sometimes two together.

CONCRETE CULVERTS.

A. W. Campbell.

A great many townships throughout the Province have largely discarded timber as a material for small culverts and sluiceways. Cedar where obtainable has been most commonly used, but all varieties of suitable lumber are becoming scarce, the price is constantly increasing, and the quality now available is far from being equal to that of former years.

Those municipalities which have experimented with vitrified and concrete tile, have, with very few exceptions, been favourably impressed with the new materials. Failure and some dissatisfaction are occasionally reported, but this in every case can be traced to causes not in any sense condemnatory of the new materials. Where any kind of tile is used there are certain requirements which must be observed. In the first instance the tile must be of good quality It is just as necessary to use good tile in culverts as in sewers: where "culled" tile are used, failure is almost of necessity the result. These tile must be perfectly sound and straight, not warped or mis-shaped in any way, otherwise good joints cannot be made, water will lie in hollow places, and culverts are apt to wash out.

Excellent culvert pipe of concrete can be manufactured cheaply in any gravel pit under the immediate direction of the road overseer. The pipes are from two to four inches in thickness, according to diameter; which latter may safely and conveniently reach three feet, in lengths of two and one half feet.

The implements required are of the simplest kind. The most important are two steel spring-cylinders, one to sit inside the other, leaving a space between the two equal to the thickness of the finished concrete pipe. By "spring-cylinder" it may be explained is

meant such a cylinder as would be formed by rolling a steel plate into a tube without sealing the joint. With the smaller of these cylinders the edges overlap or coil slightly; but are so manufactured that the edges may be forced back and set into a perfect cylinder. Accompanying these moulds are bottom and top rings, which shape the bell and spigot ends of the pipe.

The two cylinders with joints flush are set on end, the one centrally inside the other and on the bottom ring, which in turn rests on a firm board base. The concrete, made of first-class cement and well-screened gravel in the proportion of one of cement to three of gravel, is then tamped firmly but lightly into the space or mould between the two cylinders. The tamping-iron used to press the concrete into place is so shaped as to fit closely to the cylinders.

The concrete is allowed to stand in the mould for a short time, when the cylinders are removed; the outer and larger cylinder by inserting an iron wedge into the joint and forcing the edges apart; the inner cylinder, by inserting the wedge into the joint and turning the edges, so as to allow them to again overlap, returning to the shape of a coil. The outer cylinder having thus been made larger and the inner one smaller, they can readily be taken away, and the concrete pipe is then left until thoroughly hardened.

Just such a number of pipe as are actually required for the season's work need be manufactured; the implements required are inexpensive, and the pipe may be made by the municipality for actual cost, which, after a little experience, can be reduced to a very small amount.

If cement concrete pipe are employed, they must be of first-class quality. They must be well shaped, as with sewer pipe, and all the rules for making a good concrete must be observed—that is, the material composing the concrete (cement, sand and stone) must be of good quality, and properly mixed. The making of good concrete is not a difficult matter, but it is sometimes difficult to find men who will follow directions. Dirty sand or gravel, too much water, careless and insufficient mixing, neglect to see that the materials are used in the right proportions, are the defects most commonly found. Concrete cannot be mixed like common mortar, and an attempt to do so is far too often made. It is affirmed by cement manufacturers that masons are the greatest offenders in

this respect; that it is almost impossible to get them to follow any system other than that to which they have been accustomed in the use of common lime; and that therefore an entirely inexperienced but practical man, who will follow directions, will often make the best concrete.

To meet with success in the use of tile culverts they must be put in place properly. They should be laid with a good fall on a regular grade to a free outlet, in such a way that water will not stand in them. The tile should be laid with the spigot end down grade, and the joints made tight with cement mortar. If the joints are open water will work its way along the outside of the culvert, and finally make a considerable channel which will allow the culvert to get out of line and finally result in a "cave-in." To prevent the water finding its way along the outside of the pipe, it is advisable to protect the ends with concrete, stone or brick head walls. Care should be taken to excavate a concave bed for the pipe, with depressions for the bell of the pipe to rest in, thus securing an even bearing, without which a heavy load passing over before the culvert has properly settled into place, may burst the tile. Tile cannot be used in very shallow culverts, but must have a sufficient depth of earth over them, to protect them from the direct pressure of heavy loads. The depth of covering necessary increases with the size of the pipe. At least a foot of earth over the top is advisable in every case, but for culverts of two feet in diameter, or over, this should be increased to at least eighteen inches.

The earth should be well packed and rammed around the tile to secure a firm bearing, and light soils should not be used immediately over or around the culvert. A heavy clay, a firm gravel, or a compact sand or gravel will answer, but vegetable mould, water sand, and light loams are subject to wash-outs. At the outlet the culvert should be set nearly flush with the surface of the ground. If set higher than the surface, the fall of water will wash out a depression, and in time will undermine the end of the culvert. A too rapid grade will have the same effect, and it is well to cobble-pave an outlet where this undermining action is likely to occur.

Culverts, in many townships, are very numerous, and necessarily so. Water should be disposed of in small quantities, along

natural watercourses, otherwise if gathered in large bodies along the roadside, it gathers force and headway, resulting in extensive wash-outs, and is in every way more costly to handle. Water should be taken away from the roads as quickly as possible, for it is excess water that is the great destroyer of roads.

Culverts, in addition to being a matter of considerable expense to municipalities, are too often in a bad state of repair, sometimes dangerous, and when not level with the roadway, are an annoyance and interruption to traffic. Good roadmaking is largely a matter of good drainage, and culverts are a detail of drainage upon which municipal councils should bestow a good deal of attention, with a view to a greater permanency, increased efficiency, and a reduction of cost.

The concrete arch culvert is, in a number of municipalities, replacing the old form of timber structure. Greater in first cost, the concrete culvert, if rightly constructed, is a permanent saving in road expenditure. The greater portion of the annual road appropriation is, in many townships, spent in repairing and re-building wooden culverts and sluiceways. The life of timber in this work is very short. Wooden culverts are quickly upheaved by frost, warped by the sun, and decayed by penetration of moisture. Wherever concrete culverts have been fairly tested they give satisfaction, and their general use by a township will mean, in the course of a few years, a marked reduction in this branch of roadwork.

The stone arch is designed on the principle that it will remain in place without the use of mortar. The concrete arch, on the other hand, is a monolith, dependent upon its cohesive strength. That the concrete arch is dependent upon cohesive strength points to the necessity, in construction, of a generous proportion of cement, very great care in mixing the concrete, and a good quality of all materials employed.

A concrete can best be regarded as a mixture of mortar and broken stone, the mortar being formed from a mixture of sand and cement. Given a sample of broken stone in a vessel, the requisite quantity of mortar can be gauged by pouring water into the vessel until the stone is submerged. The quantity of water used will indicate the amount of mortar required to completely fill the voids in the stone. The proportionate amount of cement needed to fill

the voids in the sand can be gauged in the same way. The proportions of cement, sand and broken stone obtained in this way would provide, with perfect mixing, a mortar in which the voids in the sand are filled with cement and each particle of sand is coated with cement; it would provide a concrete in which the interstices of the stone are filled with this mortar, and each stone coated with mortar. This would be the case with perfect mixing, and would provide a theoretically perfect concrete. Perfect mixing is not possible, however, and it is necessary to provide an amount of cement in excess of the voids in the sand, and an amount of mortar in excess of the voids in the stone.

With proper mixing and good materials, a satisfactory concrete for bridge abutments can be formed from cement and broken stone, in the proportions of one, three and six. It is recognized that the greatest strength in concrete can be obtained by making the mortar rich in cement, rather than by lessening the quantity of stone, but beyond providing for a strong adhesion of mortar and stone, little is gained by making the mortar materially stronger than the stone. The foregoing applies to crushing strength, however, rather more than to the tensile strength required to some extent in the arch. For the arch proper, it will be well to use a richer concrete, in, say, the proportions of one of cement, two of sand, and three of broken stone.

The cost of the abutments may be lessened, where they are of sufficient thickness, by the use of rubble concrete. The casing or curbing must be built up as the laying of the concrete proceeds. Within the casing and firmly tamped against it, there should be placed fine concrete to a thickness of about six inches. This will form a shell for the abutment, inside of which large stones may be placed in rack-and-pinion order, ends up. There should be a space of at least two inches between the stone, filled with fine concrete, and all firmly rammed. The outer shell of fine concrete should always be kept built up six inches or so in advance of the rubble work. The rubble should be placed in layers, each layer well flushed with a layer of fine concrete.

The lumber used in making the curbing or casing should be dressed, tightly fitted and firmly braced, so that the concrete may be well rammed into place. The framework should be closely

boarded up against the work as it proceeds. The centering for the arch should be well formed. The ribs should not be farther than three feet apart. The lagging should be three inches thick and dressed to the intrados of the arch. All the framework, centering and supports should be substantial and well constructed. This framework is a considerable item of expense in the building of a culvert, but it can be used as often as it may be required for arches of similar span. The exterior of the culvert when finished should have a smooth face, free from holes; and a surface coating, which is of little use, should not be necessary.

There is some difference of opinion as to the relative strengths of gravel and broken stone in concrete. The natural inference is to suppose that a rough, irregular surface will secure greater adhesion than one that is smooth. However that may be, there is little reason to doubt that gravel will make a good concrete, but there is a right and a wrong way of using gravel. It is not uncommon to find cement and gravel just as it is taken from the pit, mixed to form a concrete. Remembering the proper composition of a concrete, and placing beside this the fact that gravel usually contains sand, but not in any definite proportions, and that some pockets of "gravel" may be almost completely sand, while in the layers adjoining there may be little if any sand, and that many gravel beds contain much clay or earthy material, it will be readily understood why it is that, in some cases, concrete mixed in this way may be successful, yet it will always be uncertain and hazardous. The only safe method is to separate the stone and sand composing the gravel by screening, then to mix cement, sand and clean stone uniformly and in their right proportions.

A cause of poor concrete is the excessive amount of water used when mixing. The tendency very often is to bring concrete to the same consistency as common mortar. Concrete when ready to be placed in the work should have the appearance of freshly dug earth. Where an excessive amount of water is used, the hardened concrete will have an open, spongy texture.

The concrete should be mixed at a point convenient to the work in a box which is sometimes specified as water-tight, but the concrete will quickly make it so. It should be mixed in just such quantity as is required, and a constant stream kept passing to the

work. It should be laid in layers, each layer thoroughly rammed until moisture appears on the surface.

It is very necessary to see that the sand and stone used in making concrete are clean, that it is free from clay, loam, vegetable or other matter which will act as an adulterant, and result in a weak and friable concrete. If such matter is intermixed with the stone it is well to flush it away with a good stream of water. Large stone used in rubble concrete should be also treated in this way. It is well, particularly in hot weather, to dampen the stone before mixing it with the mortar. The heat of the stone in hot weather causes the moisture of the mortar to evaporate, causes it to set too quickly, and at all times there is more or less absorption from the mortar in immediate contact with the stone, unless the stone, as intimated, has been dampened.

When the work ceases for the day, or is for other reasons interrupted, the surface of concrete should be kept damp until work is resumed. When work is in progress in hot weather, any exposed surfaces should be kept damp and protected from the rays of the sun, otherwise the surface will, in setting too rapidly, be interlaced with hair-like cracks which, filling with water in winter, and freezing, will cause the surface to scale off. The same scaling sometimes results from laying concrete in frosty weather.

Arch culverts of masonry or concrete fail frequently from settlement caused by an insecure foundation. The foundation should always be of at least sufficient depth to be free from any danger of undermining by the action of the water, and of sufficient further depth to be safe from settlement.

A MODERN SHIP-BUILDING PLANT.

J. Roy Cockburn, '01.

In view of the fact that ship-building is yearly becoming of greater importance in both Canada and the United States, as well as in other parts of the world, I venture these few remarks on the subject.

If Canada wishes to compete with other countries in ocean and lake transportation, it is important that the ship-building industry should be developed. Canada has certainly all the necessary resources. Perhaps the only difficulty is that labour is somewhat more expensive here than in some parts of the world, but it is not more so than in the United States.

Nearly all the great shipyards of the world are the result of a great many years growth and development, and were started years before the advent of great labour-saving machinery, so that when such equipment was afterwards installed it could not be used to the greatest advantage. This objection does not exist, however, in the case of a new plant being built.

To the best of my knowledge there is but one large ship-building plant in the world where everything is arranged and laid out in a thoroughly up-to-date manner. I refer to the plant of the "New York Ship-building Co." of Camden, N.J., where I had the pleasure of working last summer and which I will now try to briefly describe.

The name of the company was so chosen that it should, in any part of the world, be suggestive of America, and also because it was originally intended to locate the plant somewhere in New York harbour.

However, the site was finally chosen at the southern end of the city of Camden, opposite Philadelphia. The property has a frontage on the Delaware River of about 3,600 feet, and a width of about 1,800 feet. The land is very suitable for the purpose of ship-building, the underlying strata being of white sand, gravel and clay.

The area of the property is about 130 acres, besides a two-acre lot on the opposite side of the street on which the main office building is situated.

The following are the chief objects which were kept in view in the designing and building of the plant:—

First—Convenience in the transfer of material from one field of operation to another.

Second—The arrangement of the ways so that ships up to 1,000 feet in length may be built under cover.

Third—An arrangement of shops that will permit of an increase of from 50 to 100 per cent. in capacity.

Fourth—Such isolation of structures as will reduce to a minimum danger from fire.

Fifth—Facilities for the ready handling of material received by rail and water.

On the side of the property next to Broadway, is a strip of land 120 feet wide reserved for ornamental purposes, and adjoining this is another reservation 128 feet wide for highway and railway purposes. There is ample room on this for six parallel tracks, each 3,000 feet long, connected with both the Pennsylvania and Reading Railroads. The buildings themselves are almost entirely free from tracks, such only being laid as are necessary for unloading material.

Track scales are provided to accommodate two cars of the largest size, and to weigh 300,000 pounds. A coal trestle has been built from which coal is dumped into bins sufficiently large to hold three months' supply.

The main building is enormous in size and unlike that in any other plant. Here all metal working departments are under one roof. The floor space is over 18 acres, and light is admitted by four acres of skylights, and two acres of windows.

There are more than forty travelling cranes ranging in capacity from seven to one hundred tons. All are driven by direct current motors. The one hundred-ton crane is carried on a span of 120 feet, and its field of operation covers the machine shop, ways, and outfitting slip, so that it may be employed to lift an engine or boiler bodily from the machine shop, and deliver it in a vessel, either on the ways or afloat. Each of the smaller cranes has its own field

of operation, and an original type has been installed, which by means of an extension arm, is able to deliver and receive material without re-handling. (this type was installed by Pawling & Harnispfeger, Milwaukee).

A great many of the cranes used for handling steel plates are equipped with powerful electro-magnets controlled by the engineer of the crane. The latter brings his electro-magnets over the plate, turns on the current, and the plate, now the armature of the magnet, can be lifted and carried to any place in the shop. It is instantly released by turning off the current.

MACHINE SHOP.

The machine shop is very large and roomy. There are three bays and one lean-to. Along each side of the machine shop run large galleries connected with the main floor by iron staircases. In the east gallery are a miscellaneous storeroom, and an electric repair shop, with lathes, shapers, drill presses, forges, etc. In the west gallery is the pipe shop which is thoroughly equipped with pipe-cutting and threading machines, lathes, drills, and grinding machines.

The lean-to contains the brass shop, a storage, and a tool room, a forge shop, and a tool manufacturing room, where a methodical system is employed for the supply of tools to the workmen, who are not required to sharpen their own tools, but return a dull one, getting a sharpened one in its place. Here also are clothes-closets, wash-rooms, etc., for the workmen, all fitted with the best sanitary devices.

The following very heavy machines are all of special design and specially built for the company: The first is a sixteen-foot vertical Niles' boring mill, fitted with three arms, two for use when the work revolves and one (the central one) for use when the work is stationary. The next machine is a large Sellers' drilling, boring and milling machine with an eight-inch spindle. This machine is equipped with steel scales and verniers for placing the work on the table, and measuring it in each direction.

There are two band saws for cutting steel, such as for cutting out eccentric straps, etc. These were built by the Noble & Fund Co., of England.

There is a horizontal milling machine from Bement-Miles & Co.; two Newton milling machines; an open side planer, 72 in. x 72

in. x 28 inches; a Betts' planer, 96 in. x 96 in. x 36 inches: two double-headed lathes, one 48 inches by 60 feet, and one 60 inches by 60 feet; two Niles' horizontal boring and milling machines, and a great many other smaller machines.

The erecting floor is in the west side of the shop and is served by two cranes, besides the 100-ton crane previously mentioned.

BOILER SHOP.

The boiler shop is directly north of the machine shop, and separated from it by a low partition only. It is also adjacent to the plate storage department, from which the plates are taken rolled by the straightening rolls, and delivered to the boiler shop.

The boiler shop is served by four cranes, one 60-ton crane, one 10-ton crane, and two 7½-ton extension cranes similar to the one mentioned before.

The hydraulic rivetter, built by Wm. Sellers & Co., is of special design. It is designed to operate with a pressure of either 50, 100, or 150 tons. There is also a 160-ton hydraulic flanging machine equipped with dies for upsetting stay bolts, flanging furnace mouths and making manhole covers.

The large boiler drill which was built by the "New York Shipbuilding Co." has a capacity for boilers from 6 feet to 20 feet in diameter and 20 feet long. It has three drill heads each containing four spindles, which can be operated at the same time, and which are adjustable in all directions.

BLACKSMITH SHOP.

The blacksmith shop is very free from gas and smoke, all the forges being furnished with exhaust hoods. There are several steam hammers as well as a complete drop forging plant, nut and bolt machine, etc.

FRAME AND PLATE SHOP.

The frame and plate shops are located side by side and adjoining the blacksmith shop. In this department are drills, countersinks, and like tools, moving over a field of 20 feet or more in diameter. Here is installed the first joggling machine in use in America, and all ships being built are of joggled plating. This machine so bends the edges of the plates that they shall, wherever lapped, present a

plane surface on the outside. There is also a scarphing machine to plane off to a feather edge the steel plates, and two Sellers' plate planers used for planing and calking the edges of the plates. At the end of this shop are the laying off tables, where the plate is marked according to the template made in the mould loft. Those plates which are to be bent are carried to the plate furnace, which is 6 feet 6 inches broad by 28 feet long. At the southern end of the shop are two rolls, one of which can handle a plate 27 feet broad, and the other is used for rolling mast plates.

THE MOULD LOFT.

The mould loft where the templates are made is located over the plate shop. At the south end of the loft is a draughting-room entirely distinct from the hull draughting-room, where about twenty draughtsmen are employed to make drawings for each shape and plate that goes into a ship. From the lines furnished by the hull draughting-room the body plan of the ship is laid down on a marble table. The offsets from this table are given to the mould loftsmen who make the templates of the frames, etc.

THE LAUNCHING WAYS.

The launching ways are at the end of the frame and plate shop and directly opposite the machine shop, where the engines are assembled. All departments, including the launching ways and outfitting slip, are under one roof, the clear height of which, above the water, is about 125 feet. The depth of water in the slip is about 30 feet at low tide. There are seven parallel launching ways, and each may be extended to build a vessel 1,000 feet long. Adjoining the slip are two piers, one 1,000 feet long, and one 1,200 feet long, each having 30 feet of water on either side.

FIRE PROTECTION.

The system of fire protection is very complete. All departments such as pattern shop, joiner shop, power house, paint shop, and rigger's loft are sufficiently removed from each other so that a fire occurring in any one may be confined to that particular one.

Water for fire protection is furnished by three 1,500 gallon pumps, through mains ranging in diameter from 16 inches down, and the outside and inside of each building is thoroughly equipped

with hydrants and hose in addition to a complete sprinkler system, so that fire risk is almost completely eliminated.

POWER HOUSE.

The power house is a building about 100 feet by 200 feet, situated on the line of railway reservation. The boilers are of 2,500 horse power and are fitted with a Greene economizer and the usual feed pumps and heaters. The smoke stack is about 200 feet high and 8 or 9 feet inside diameter. It is large enough for boilers of double the capacity of those now in use. There are two main engines of 750 horse power each. They are cross-compound Corliss, having cylinders 18 inches and 36 inches diameter by 42-inch stroke, and make 120 revolutions per minute. They are direct connected to two 500 K. W. generators of the rotary converter type, supplying both direct and alternating current, the latter being of two phases. In addition there is a 50 K. W. direct connected, direct current generator. The exhaust may be led either to the open air, to a jet condenser, or into the heating system of the shops. All the large machine tools are driven by direct connected induction motors. The general illumination is by about five hundred enclosed arc lamps, while the offices and individual tools are lighted by incandescent lamps. Compressed air is supplied by a compressor of 5,000 cubic feet capacity per minute, at a pressure of 120 pounds per square inch. Hydraulic power is supplied by two compound pumps each having a capacity of 400 gallons of water per minute, at a pressure of 1,500 pounds per square inch.

The three kinds of power are carried underground to the main buildings, where they are distributed. The great advantages of a system of power transmission without belts or line shafting are so obvious that it is not necessary here to make further comment on the subject.

The drinking and general service water is taken from artesian wells on the premises. It is pumped to all parts of the plant and has a uniform temperature of about 56 degrees F. The plant has also a complete and up-to-date sewage system.

OFFICE BUILDING.

The office building is a plain structure on the east side of Broadway. It contains two large draughting rooms, where about one hun-

dred and sixty draughtsmen are employed, blue print rooms, library, fire-proof vault, and all necessary offices and rooms. The basement contains a bicycle room, a museum, three large dining rooms, with accommodation for two hundred people; and toilet rooms for those employed in the office. There is a complete telephone system connecting the office and all departments, as well as a staff of messenger boys who run errands round the plant.

An ingenious system of marking material has been adopted, by means of which the ultimate destination of any piece is indicated. A whole number is employed, which is the number of the ship to which the piece belongs; the first number to the right designates that the part belongs to the hull or machinery or other part, etc. The number 1.5421 on a casting indicates the following:

(1.) means that it belongs to ship No. 1.

.5 means that it belongs to the machinery.

.04 means that it belongs to the main engine.

.002 means that it belongs to the bed plate.

.0001 means that it is No. 1 section of that bed plate.

2.5421 would mean the same part for ship No. 2.

They intended to employ about 5,000 men when all departments are full. My number was 4,422, so that gives a fair idea of the number employed..

Last summer the company had under contract about ten ships varying in size from 310 to 625 feet in length. The company was organized in the spring of 1899, with a capital of $6,000,000.

To sum up, the New York Ship-building Co. has now in Camden one of the greatest of ship-building plants. It has contracts on hand that give it sufficient work to establish it on a firm basis, and it will without doubt, if wisely managed, prove an engineering and financial success; let us hope to see in the near future a similar institution in this country.

THE YOUNG GRADUATE AND THE PROFESSION OF MINING ENGINEERING.

H. E. T. HAULTAIN, C.E., A. M. CAN. SOC. C. E.

Both in my own experience and in my observation of young graduates from engineering schools in all parts of the world, I have found a general ignorance of the profession as a whole generally, coupled with a very much distorted view of the young graduate's position in, and relation to, his profession. This is probably to a very large extent unavoidable, but it has always seemed to me a very important point, and I should strongly like to see a series of lectures on the subject embodied in the general curriculum of the school. Doubtless very much of such knowledge must be personally and painfully learned by experience, but a very valuable skeleton of information could be built up in the lecture room. In the short time at my disposal, I will attempt an outline of the profession of mining engineering as I in my limited experience have found it, and attempt to deal with some of the more prominent difficulties that will be encountered in the early days of the Young Engineer's career.

Kipling says:

> "When the waters were dried an' the earth did appear,
> The Lord, He created the Engineer."

And, from the first, the mining engineer must have been a man of prime importance in his class. As time went on, and all structures depended more and more, either in their fashioning or in their material, upon the supply of metals, so would the importance of the miner become greater. In France and Germany this is recognized, and mining engineering ranks ahead of all other branches of engineering, but in our English speaking communities it is not officially accorded the same recognition, and possibly the miner is often considered rough and unfinished in his methods, a pioneer occupied in coping with nature in the rough and lagging far behind the polish

and finish of the scientific engineering of the cities. It is true he is a pioneer and that he deals with the forces of nature in her crudest and roughest forms, but he does it with a wider range of scientific knowledge than that possessed by any of his engineering brothers. He needs and he makes use of the specialized knowledge of all other branches of engineering in addition to such that is peculiarly his own.

The profession of mining engineering embodies very much more than any one man's mind could possibly encompass, and there is a limitless number of subdivisions or combinations of subdivisions for the specialist in which to bury himself.

In general, mining engineers are divided into two main classes, viz., *Mining Engineers* and *Metallurgical Engineers*. Under this classification in its closest sense, the mining engineer has to do with the getting of ore to the point where it lies in a broken state at the surface, and the metallurgical engineer carries on the work from this point, until the metals are finally extracted from the ore. But as a general rule the metallurgical engineer's work is confined to smelting operations, while the processes of mechanical concentration of ores, and even the leaching and lixiviation processes, are in the hands of the mining engineer in charge of the other mining work. The reason of this is to be found in the fact that as a rule the mechanical concentration and the lixiviation of ores is carried on at the mine under the one management; while smelting is generally done at some central point at a distance from the mining operations. The department of smelting I must leave out of consideration, and trust some other graduate will take up this very important branch.

Of mining engineers proper, there is a rough classification that will divide them into two classes: the engineers connected with the large permanent mining centres, usually coal and iron; and those connected with the general mining industry scattered all over the world. It is with the work of the latter class that my experience has been, and it is with them that I will deal. This class of mining engineers is again subdivided into two main classes—the consulting engineer and the managing engineer, and the thoroughly competent consulting engineer will have passed through the stage of managing engineer. The work of the consulting engineer can be divided into two main divisions — reporting on the value of properties and reporting on the management of properties. The term managing

engineer would embody in its general sense all the engineers resident about a mine, and would include assayers, chemists, surveyors, mechanical engineers, electricians and those engineers skilled in concentration and lixiviation processes.

The prominent consulting engineer would have his headquarters at some commercial centre—London being the particular home of this class—and he might or might not have assistants or partners in parts of the world nearer to the mining centres. A large part of his work—perhaps his sole work—would be the examining of, and reporting on, the value of mining properties in various parts of the world. This is of course most important work and is correspondingly paid for. In this work experience and judgment, built upon a foundation of wide scientific knowledge, coupled with a well balanced commercial sense and the necessarily ever present disinterested integrity, are the main requirements. It is a position of the utmost commercial responsibility, a single report often controlling the investment of millions. The keynote of success is of course Reputation, and before a man could expect to succeed at this work, he must have built up a reputation, and have made friends. The fees for this kind of work are high. Among prominent London engineers the fee for a report of any consequence would not often be under $5,000.

Consulting engineers located in either commercial or mining centres also undertake the reporting on the management of mines. They may visit the mine at intervals, or they may simply base their reports and advice on the information, accounts, etc., supplied to the company by the mine manager; and their advice might extend to the supplying of detailed plans for development or for machinery. Consulting engineers in this capacity are frequently engaged by London companies owning mines abroad.

The position of a consulting engineer with a reputation, able practically to choose his own work, travelling in many parts of the world, returning always to his headquarters, and receiving most substantial fees, is a most enviable one, and is one looked forward to as a natural consequence of years of successful work in the field.

But it is to the position of a managing engineer and the steps subordinate to that position that I would more particularly draw

your attention. Perhaps I could not do better than outline the duties and responsibilities in an actual case.

Take the case of a manager of an English Company owning mining territory in Africa. They have one mine partially developed and several prospects giving more or less promise of good values. The Company is managed in London by a board of directors—non-technical men — with a chairman at their head. This Board will meet once a month, or once a fortnight, and will outline the general policy of the Company. The details as far as the London end is concerned are in the hands of the chairman, who relegates them largely to the secretary, who corresponds with the manager in Africa. The manager will have a wholesale power of attorney to do anything and everything in Africa, and will be answerable for all his actions directly to the Board. He will have an agreement or engagement as manager, terminable as a rule by six months notice on either side. He must of necessity have had the full confidence of the Board before he was appointed, and must retain this to the full or his position will become untenable. The Board will be completely at the mercy of the manager—their only information being what he chooses to give them in his letters and reports, together with that obtained through an annual visit of a director or a consulting engineer. The manager in turn will be very much at the mercy of the misunderstandings and disappointments of the Board, and nothing but full confidence can keep things running. The keeping of the Board well and judicially supplied with information is perhaps one of the most important functions of the manager.

Coming nearer to his work, we find him in charge of an isolated community twenty miles or more from a settlement—100 miles from a railway—with slow-going ox-wagons as the only means of freight transport.

First and foremost he must examine his ore deposits and then with all the knowledge that he possesses of geology and mineralogy, he must form some opinion of their probable value and outline a method of development. With his already partially developed ore deposit, all his past experience of the costs of mining and ore treatment, together with all the information he can obtain in a raw country concerning labour, power, fuel, transportation and markets, will leave him in no high degree of certainty as to probable profits.

He has to study the resources of the country, and to design his plant accordingly. He is alone, single handed, and up against the real thing. And he has to organize in a bare wilderness a large and complex business. While keeping his mind keenly on the deep scientific problems of his various and varying ore deposits, on the problems of haulage, timbering and ore treatment, he has to arrange for the establishing of his camp, the housing of his men and animals, the purchase of innumerable supplies, and transportation over difficult country. He has to procure, and very often to a large extent must be prepared to train, a most varied gang of workmen, skilled and unskilled, in all branches of labour. He has to control a most mixed lot of the roughest class of men, both white and black; at all times he must preserve his personal influence and tone. He is the single-handed autocrat of an isolated community, with nothing to maintain his authority but his own personality. He is spending large sums of money, and spending it in innumerable ways that are difficult to trace and check. On all sides are men trying to get the best of him in every proposition, and he must have the business side—the commercial side—of his work organized to a degree unthought of in many establishments nearer the centres of civilization.

While organizing and personally controlling these varied complexities, he must ever keep a clear mind for the constant, careful and well balanced study of the intricate scientific problems of his work.

Let us consider some of these engineering problems:

In the first place his ore bodies differ in many respects from any he has had any previous knowledge of—no two ore bodies are the same. Nothing but experience—wide and varied experience—founded on a scientific training, is going to save him in the solution of the problems involved in the exploration of his ore bodies.

He has one ore body so far opened up that sufficient values are in sight to justify the installation of machinery on a large scale for the breaking, mining and treating of his ore. Upon all the intricate details I cannot touch, but let us look at some of the main problems involved.

The first problem of mining his ore and protecting his underground workings is one depending almost entirely upon judgment and foresight based on experience, and is one that no amount of

training or reading can solve for him. In any case he must work tentatively—must feel his way. That probably is the keynote of all underground work—certainly of all the early stages. It is impossible to see far ahead, and one must feel his way foot by foot, planning to-morrow's work by to-day's results.

But the planning of the ultimate development which must soon be taken in hand is a large problem involving work spread over many years, and the general skeleton of the plan must be laid out and undertaken at once. Upon the position of his main working shaft or tunnel the position of his surface works will to a large extent depend. Into this problem must enter the problems of pumping, ventilation, and haulage, and much calculation and well balanced judgment are required for a satisfactory solution. The problem involves not only a very large sum in itself, but it will always very seriously affect the working costs.

Inseparable from this problem is the question of power. The case I have in view has practically unlimited water power five miles away, so that the question of power does not affect the hoisting question; and it is found that for the first few years the most satisfactory course is the running of a low level tunnel which will give several years ore supplies above it, and which will always be the main working tunnel.

The next problem is the treatment of the ore, and though the manager ought to be capable of dealing with this problem himself, he may call in the assistance of a consulting specialist.

And here comes in a very nice point:

It is of course out of the question that our mine manager should know everything, or that he should know as much of detail as a specialist in any branch, and very naturally the average business man will say: Here is an isolated problem, let it be solved by the specialist.

In the large mining centres are to be found consulting engineers, who are disinterested specialists in milling and lixiviation processes, and who make a business of such problems. They often are called upon to supply complete plans.

In the first place, there is one statement that will hold under all circumstances:—There is no isolated problem connected with any

mine. The mine and everything connected with it is one vast complex machine, with all its parts and details interdependent, and smooth running—successful running—depends on the balance between all its parts, and upon their perfect inter-working. This can only be achieved in one mind. There must be only one controlling hand, and though it is not necessary for the manager to design all the details, he must fully grasp the essentials of every department. He must be responsible for everything.

If outside consulting advice is called in, it must be in consultation with the manager, and if the manager is incapable of dealing with the subject, a most dangerous element of failure is at once introduced. This is a most essential element of mine management and I will refer to it later on.

If a thorough professional consulting engineer with a reputation is called in to settle the problem of ore treatment, he may be prepared to deal with it in its entirety, in which case he would go carefully into all the conditions surrounding the problem from the ore deposit to the market, and would do this in close consultation with the manager, whom also he would carefully consider as an important condition. Then after designing the plant he would to a certain extent supervise construction, and on its completion would personally attend to the early stages of its operation. For an ore treatment plant is not like a small steam engine which will run when supplied with steam. Even after most careful and capable designing, there will have to be much adjusting of its method of operations before the best results are obtainable, and this adjusting must be done by a capable and responsible head.

If the specialist's connection ceases on the delivery of the plans, the manager's responsibility will only then commence, and if there be any failure in results the manager will blame the design and the designer will blame the method of operation, and the company will be in the position of the man trying to sit on two chairs. This is one of the commonest causes of failure and trouble in mining, and every mining man can point to many incidents of this kind.

In the case I have described, the specialist's fee would be enormous—probably much larger than the manager's annual salary.

Most frequently it would not be possible to obtain the services of a distinguished specialist, and recourse is often had to the

manufacturers of mining machinery. They call themselves specialists in such matters and very often are so, and have much experience and data at their command, but we then have the anomalous position of the consulting engineer and the contractor being one and the same person. It is surprising how frequently this is the case, and it is not surprising that this is most frequently a cause of disaster.

The manufacturer can never be a disinterested party. Conditions do not permit him to make a thorough examination of all the conditions. He will tell you what machinery to put in: it will be his own and there will be as much as possible of it; it will be good machinery, and he will guarantee the smooth running of individual machines, but he will not guarantee the results. And he will have many excuses to show that the blame of failure is not attachable to him. He will tell you that the ore treated in the mill differs from the sample sent him; that the construction was poor and the operation is worse. You cannot pin down the manufacturer to results—he is too old a bird at the game.

What then is the manager to do?

He ought to be capable of designing his own plant. If he feels doubts about it, let him engage a man who has knowledege of such matters, engage him as an assistant—as a head of a department—and let this man experiment on a laboratory scale in co-operation with the manager.

After the manager, with or without outside aid, has decided that his ore is a free milling ore requiring a subsequent treatment of tailings by cyanide, and has decided on the general main idea of his plant, he can safely go to the manufacturer for his machinery, trusting largely to him for all details—for the details are the work of a mechanical engineer, and in this department the manufacturer is the highest specialist.

The first plant will doubtless be a small one, designed with a view to further increase, and also with a view of permitting considerable experimenting.

What I have said in regard to the ore treatment plant also holds good with the tramway from the mine to the mill, and with the water power plant, and with the electric transmission plant, with of course some modifications.

Aerial tramways come nearer to being isolated problems than does any other part of the plant, and they are very frequently given over to contractors, who guarantee to erect the tramway and run it for a short time. To a certain extent the tramway can be looked upon as an isolated machine of the nature of a steam engine. But again to make the contractor and the consulting engineer the same person, even in so simple a matter as a tramway, tends to an unnecessary waste of money and consists in paying to a contractor very much more than what is already paid to the manager or his staff for the same work.

In the case of electric machinery — electricity is perhaps somewhat removed from the mining engineer, but is daily becoming less so, and though the mining engineer would certainly never attempt to design his dynamos, he certainly ought to know enough to decide whether he wanted direct current or alternating machinery and to be able rationally to check over the electrician's figures as to line loss, etc., etc.

To sum up this question of machinery, the manager should be thoroughly conversant with all the standard types of machinery of all the prominent manufacturers that might possibly be of use in mining work, and this includes practically everything except heavy ordnance and marine engines, though the knowledge of heavy guns possessed by the mining staff in Kimberley was of considerable value last year. With the detailed design of this machinery he need not unduly burden himself beyond understanding the why and the wherefore of every part. The manufacturer can be depended on for excellence of detail. Thereon depends his existence.

The erection of his plant is an all-important part of the manager's work or of a most trusted assistant. To let this by contracts generally ends in disaster unless most competent and keen watch is kept on the contractor. Generally speaking, in all mining construction it is more satisfactory and more economical to watch over a good foreman than to check a contractor. The contractor, like the Indian, will be bad if he can be.

The operation of the plant will be the work of the heads of departments always under the personal eye of the manager.

This is a bare skeleton of the work of the mine. It is filled in with an interesting network of details of every kind, from the

niceties of subtle chemical investigation to the handling of a drunken mob, and through it all must run side by side the deepest scientific thought and the most cold-blooded business methods, tempered always by the truest disinterested professional tone.

The manager will have to assist him in his work, besides his own personal assistant, several heads of departments—a commercial superintendent in charge of the buying and of the books and the commercial side of the business generally; a surveyor, an assayer, superintendents or head foremen of mine, mill and cyanide plant, a master mechanic, and foremen of the various sub-departments, and with these the successful manager will keep in very close, intimate touch.

There is another phase of the manager's work that I have not yet touched upon—a department in which he remains alone.

The mine is the property of a company, and the public pay very much more attention to the shares than they do to the mine, and the majority of shareholders expect to make very much more out of the fluctuation in the price of shares than they do out of the mine. There is a constant and active buying and selling of shares. Now the manager's regular reports to his Board can very materially affect the price of shares and his plans of operations do also very materially affect the price of shares; discoveries will be made in the mine that will make enormous differences in the value of the stock. In very many ways the manager has a very large control over the price of the stock, and if there be any deviation on his part from strict honesty, from the true professional spirit of disinterestedness, he may be in a position to make much money for himself or his friends. Here is a wide open temptation—a temptation so coarse and glaring—so palpable—that it will in general be easily avoided, but it has also its more subtle aspects, and the only protection a man has lies in the inherent honesty, the professional spirit and tone of the true engineer.

This is an outline of the position of a manager of by no means large property, and may be taken as a fair general example.

As an example of the extent to which the business of mine management may grow, I would cite the case of The Consolidated Gold Fields of South Africa. In 1897, in their engineering offices in Johannesburg, they had fifteen draughtsmen in the surveying department, and seventeen more in the general department. Their

chief engineer drew a salary of $60,000 a year, their chief mechanical engineer drew $25,000, and so on. Of course this office did all the engineering work for a large group of mines.

But it is the smaller propositions that tax the resources of the mining engineer most severely, for in these cases he must himself control every department and must carry out works that in larger concerns would be in the hands of heads of departments in themselves specialists capable of carrying responsibility.

In an examination of the duties of the mine manager, as I have outlined, what do we find as the more prominent points? I think we shall find that the most important point of all is confidence—mutual confidence between the directors and the manager. To obtain this the manager must be a man of experience—a man with a record—a man who has made friends. The next point of importance is the fact that the whole concern, first, last and all the time, is a business proposition undertaken with the sole and only purpose of making money, and as far as our engineer is concerned, making money legitimately, though—and this is a point ever to be remembered by the young graduate—there are always those seeking to make money illegitimately. The whole concern in every department must be organized on a commercial basis. The third point of importance is the essentially scientific character of all the problems involved in the finding, winning and treating of the ore. In the young graduate's technical course, his whole time and energies being occupied with this latter point, he is apt to lose sight almost altogether of the other two. But these three points are as inseparable as the three dimensions of space, and any proposition founded on two only will be a failure.

Of course there is an exception to this rule—the factor known as luck may once in a thousand times upset all rational conceptions.

Besides these three fundamental points there are others of nearly equal importance. All mining work is new work; every problem is a new one, differing in many respects from the engineer's previous experiences; every problem is complex, involving a large number of facts and conditions often very obscure. The engineer must be a man of varied experience, not only conversant with a wide range of scientific knowledge, but with a very wide range of actual experience. He must be essentially quick witted and he must have

a lively technical imagination, ever ready to imagine new combinations and possibilities. But his temperament and technical character must be strong enough to allow this technical imagination full play, without its carrying him off his feet into a wilderness of conjecture.

He must be physically strong—able to live anywhere and eat anything: he must ever be ready to pack his blankets and his scientific knowledge on his own back.

He must be a professional man in the fullest sense of the term. He must have *tone*; I cannot define *tone*, it marks quality, or shall I say *quality* marks *tone*. And tone is as unassailable as it is hard to define. From the first step to the last the mining engineer is surrounded by temptations of every kind; every tendency within him will have free opportunity to pull him towards disaster. From the start he is away from the influence of custom and social ties, and he who has never been absolutely free from these influences can have little conception of the extent of their controlling power. But the temptations arising from avarice and ambition are the most continually and persistently present. And these temptations are often of the subtlest kind—most frequently not having even the appearances of temptation, and this is a phase of his work in which the engineer stands alone—a game in which he must play a lone hand.

Somebody—Gilbert Hamerton, I think—has said that the most important characteristic of a critic should be disinterestedness. Disinterestedness is the foundation and skeleton framework of the whole structure of the professional man. If he is not disinterested he is nothing. He is an employee and his interests always must be on behalf of his employer. This explains how the mine manager can be a business man and still a professional man. He is carrying on business for another and he can carry it on only in the cleanest and straightest of business methods.

Another thing to be observed in the work of our mine manager is that he has more to do with human nature than with any of the other forces of nature. He has to deal with his directors on one hand, and with his employees on the other. He has to deal continually with the cleverest scoundrels and rogues of all classes and kinds. He has to depend on his judgment of character in black, red, yellow and white.

Well, gentlemen, have I painted an impossible picture for you? I have outlined the main skeleton frame of a possible structure—a structure for which there is an enormous demand; the completion of the edifice depends upon the individual.

So much for what there is in front of us. Let us now consider our first steps.

The young graduate, despite his hard work and scientific attainments, is, as an engineer, well nigh as useless as the new-born babe. I know you will not believe this—it is not compatible with your years and your efforts—it is probably just as well that you don't believe it, but it is one of the first important things that you must learn in the outside world.

How is this so? Thus: the young graduate has had no experience (I know there are exceptions), consequently can have no judgment, and therefore is absolutely incapable of responsible initiative.

Many people will tell me I am entirely wrong—that the young graduate is full to overflowing with judgment—that he will judge anything or anybody, and as for initiative, he has the nerve and the supreme self-confidence to tackle any proposition—to initiate anything. Exactly—that emphasises what I mean—he has no judgment—that is, no judgment that can be depended upon.

In England they put the embryo engineer in an incubator—that is—he is articled as a pupil for one, two, or more years to an engineer of standing and experience, and for this privilege he will pay as much as $1,000 a year, and will receive no pay of any kind in return for his work. With this idea I would be wholly in accord, if the conditions in the colonies permitted it. I would not advise for a colonial mining graduate an articled pupilage in England; but if a western mining engineer would take him, he could not possibly do better. But out here the conditions are different, and we have to face conditions as we find them.

In the first place, many of our technical graduates have not the means to pay any pupilage fees, nor even to give their services and time for nothing; they must earn soon after graduation. And again I do not think you could persuade any mining engineer in active work on this continent to accept pupilage fees or to have about him a pupil working for nothing.

The young graduate must earn money, and it is a function of the technical school to leave him in a position to do this, and there are two or perhaps three or even four branches of work in which the technical schools can turn out commercially useful men. I refer to assaying and surveying, and to a certain extent, draughting.

The school can—if it chooses—turn out men who could take hold of the position of assayer or of surveyor at any small mine, or who would make excellent assistants on a large property. These positions require practically no judgment or initiative, and the main difference between the work at the school and the work at the mine, consists in the rapidity that is required in commercial work, and a certain ability to make shift with the anything but ideal conditions and appliances that one may be up against. If to a smooth working knowledge of assaying and surveying, the young graduate has added an active knowledge of book-keeping and cost-keeping, he has three strings to his bow that will earn him a living in any active mining camp.

It is a common saying in the West that if you cannot get one job you should take two, by which is meant that you may often be able to get a job as an assayer and book-keeper combined where you could get nothing if you applied for either singly. My advice to any technical school would be—make book-keeping and cost-keeping and the commercial organization of engineering business, an important part of your curriculum. My advice to any student of a school where this is not part of the curriculum is, to take steps to make a special study of these subjects at the earliest possible opportunity.

The obtaining of a position as assayer or surveyor, and, from that position, studying the actual working conditions of a mine, to be ready for further advancement in your profession, is the orthodox method.

The surveyor has the better opportunity—he is here, there and everywhere on the property—mixed with everybody and sees everything that is going on, and will be more naturally given the position of acting manager or assistant manager.

However, before going any further, let us consider more fully the functions of the first few years after graduation. The first function doubtless is the earning of a living, and the orthodox way

of doing this I have outlined. But if you stop at that, you will never be an engineer. The main function is to get experience—wide, varied experience—of everything you will need in after years. Another function is to make professional friends, but the main point is experience.

In your S. P. S. course you have had a most excellent training. You have been trained to think—to reason—to read and to a certain extent to observe—you have been trained to ask the question "why?" and to make an effort to rationally answer that question. You have learnt much about the physical laws underlying all engineering problems. The excavations have been dug and a very substantial foundation has been laid for a very elaborate superstructure; and further than this, the skeleton steel frame work has been in part erected; and even still further, if the material for further erection has not been gathered, the method of obtaining it has at least been indicated. You can live in the cellar if you like, but that will never make a house of it—you will never be an engineer. You must build on the foundation. You must fill in the skeleton frame work—you must erect extensions to your frame work—this you must do alone. Nobody else can do it for you. The elaborating of the structure is by personal experience.

In my student days Prof. Galbraith advised us to devote the first ten years after graduating to the sole function of gaining a varied experience. I think this most excellent advice.

No matter what position you hold you will be gaining experience, and to gain a varied experience you must not stay too long in one position. But you must not trust to hap-hazard luck in the positions you get. There are several points to be remembered. In the first place in your early days you can do things that later on in your professional life, you could not do. For instance, on graduating you could work as a mucker or common labourer underground—or you might innocently be employed by some notoriously corrupt men or companies. In neither case would your reputation suffer and you would be the gainer by some valuable knowledge.

The most prominent feature of mining work in all parts of the world (and in Canada and in Ontario have we had most scandalous examples of it) is the extreme corruption, crookedness and dishonesty that frequently accompanies it. This exists to a degree

beyond all conception by those who have not actually seen it. If you keep this fact in view and remain always ready to quit a job when it looks dirty, you can in your early years take pretty nearly anything you can get, but later on you must be more careful what you do. Then the main point would be to get near good men, near good companies and successful concerns.

In your early years there are several very unorthodox things that I would advise. In all mining work the biggest item is for labour, and there is no other item of expenditure in which money may be lost or saved to the same extent. The human machine is not only the most used, but it is the most complex, and to be a successful mining man you must understand your workman. The best place to study your workingman is alongside of him. I strongly advise every young mining graduate to work as a mucker or trammer underground in some fairly large mine. To do this properly you must do it thoroughly and drop all your engineering business, and your diploma and all that, and get into dirty overalls and get your job from the foreman and sleep in the bunk-house and keep away from the office. This I know is often advised, and in Cornwall and Freiberg there are regular practical courses underground where the students play more or less seriously at work and learn after a fashion to swing a hammer and frame a set. Candidly I don't think much of that—I do not see that such work is of very much use, and in those practical courses you don't learn anything of the men—you don't get round to their point of view. This to my mind is the essential point, and my advice is to get a mucker's job and hold it at least over one pay day and over several if you can. It will hurt and it will be hard, but it will be worth it.

Again, if you have any inclination towards carpenter's work or machine fitting or any opportunity to follow up such work, I say by all means do so. I know of no better qualification for a young man seeking mining experience than a knowledge of machine fitting. There is no part of a mine free from machinery, and the fitter is wanted everywhere and gets a job more easily than any other class of skilled or semi-skilled workman; while a carpenter can often get a job on mill construction or the like that will give him an insight into construction that he could get in no other way. These are not short

cuts to success or by-paths—they are stepping stones and most valuable ones at that. I would strongly advise the mining student to spend at least one of his summers in a machine shop or a carpenter's shop. I would consider this better than a summer spent in an assay office, on survey, or in a mine.

The next question is as to where the young graduate is to go on graduation. Into the question of a post-graduate course I cannot go beyond saying that I am in favour of a post-graduate course, and would still recommend Freiberg despite all the advances made by technical schools on this continent.

After the completion of his technical course he should go to some *active* mining camp, and I certainly would choose the Western States. I am enthusiastically a Canadian, but I do not advise the young mining engineer to remain in Canada. He should go to an older mining country for his experience, and the United States—the Western States—has trained and still is training the world's most prominent engineers. And when you go west leave your diploma behind you, also your testimonials and recommendations. You will be looking only for subordinate positions, and for these positions men will size you up by looking at you and will discharge you as casually as they engage you. Never be afraid of quitting a a job. It is no disgrace—very often it is not a bad thing to be discharged. A willingness to turn your hand to anything and everything that comes your way and do it with your best effort, are traits that will help you more than others. It will be several years before you get to what your heart pines for—that is, real engineering work—but you must not neglect it for that reason; your eyes must always be open to everything about you, and you must read everything you can lay your hands on—technical magazines and catalogues in particular.

You will probably find the life a hard one, full of painful physical effort—full of misunderstandings and disappointments. Hope will be long deferred. Your scientific attainments will seem lost—swallowed up by chance and the force of circumstances. You will think you are losing all your finer feelings—your social niceties; the latest operas and plays will hardly be known by name to you and the popular airs will be three years old when they reach you. Life will be anything but a soft snap and your only consolation will

often be: "Well, it's good experience, and anyway, it's all in the day's work!" You will find that you will have to give up very much, if not all that went to make life pleasant, and you will get in return—if you are lucky—work—and in many years—if you are lucky—well paid work.

But you will see—and if your eyes are open, life will be very full—you will play your own game with a freedom and a scope unknown in any other profession. You will have opportunities to carry your tendencies to the full. You will be with men and you will work with men, and the conditions and surroundings will be such as to bring out, in full prominence, the characters good and bad of men. Veneer and polish will be absent, and if you are a lover of men you will love your life. If you want an easy life leave mining alone. If you are not a tramp and want everything settled—if you are contemplating early marriage—don't go in for mining, for you will have to live and work where it would not be fair to take her.

Let me finish up by giving you some disconnected bits of advice on matters in general.

Treat every friend as if some day he might be your enemy, and treat your enemy as if some day he might be your friend.

In making investigations or examinations take absolutely nothing for granted.

Trust everybody *but* cut the cards.

Keep your face shut.

In everything remember first that you are a professional man.

Kipling says:—

> "There are nine and sixty ways of constructing tribal lays,
> And every single one of them is right."

There are also nine and sixty ways of skinning a cat or doing anything else, and very often every single one of them is right; it depends on circumstances.

In other words, different circumstances will demand different methods. Do not be afraid of new methods.

Nelson, B.C., February, 1902.

THE POSITION OF AN ENGINEER AS ARBITRATOR UNDER THE CONTRACT.

Angus MacMurchy.

The employer appoints the engineer under the contract, and the contractor has to accept him. He has no choice or option in that matter. Not only must the contractor execute the works in accordance with the directions of the engineer under the contract, but the engineer is usually made the sole judge of the quality and sufficiency of the works when executed, and the engineer is also most frequently made the final judge in any dispute arising under the contract between the employer and contractor. Thus it will be seen that the functions of the engineer as arbitrator are both extensive and important.

The engineer is responsible to his employer under the contract; to the contractor he is responsible by law only in case of fraud or misconduct. In legal phraseology there is privity between the employer and the engineer, but there is no privity between the contractor and the engineer. The consequence of this is that the contractor has a cause of action against the employer only, unless the engineer has been guilty of fraud or deceit while acting under the contract. But the contractor in a proper case has an action against the engineer for negligence in the discharge of his duties.

For many purposes, the acts of the engineer and the owner or company [illegible] him are identical or rather equivalent. As [illegible] orth, his position is not quasi judicial. [illegible] Ry. Co., (1854) 5 H. L. C. at p. 89.

If an engineer acts bona fide according to the contract, that is quite enough to make his acts valid and binding upon the contractor. So long as the engineer has no concealed interest in the contract or secret relationship to the parties that will certainly bias his judgment, his acts will receive due weight, in fact he may almost be called the judge in his own case.

The contractor, however, is not always bound by the decision of the engineer, as, for instance, in a case decided in 1818, Kemp v. Rose, 1 Giff. 258, the builder was bound by the contract to accept the decision and certificate of the architect as to the amount to be paid for his work, but the builder did not know that the architect had promised the employer that the work would not cost more than a certain sum—in that case the Court did not consider the decision of the architect made under such a bias binding.

The last reported case on this subject comes from Chatham and is just to hand. There the superintendent under the contract was the uncle and "drowned in debt" to the owner. This was unknown to the contractor, who brought an action to recover the balance claimed by him without procuring the superintendent's certificate. It was held by the Court of Appeal, Chief Justice Armour's vigorous intellect brushing aside, as usual, formal and technical legal defences, that the relationships. "family and financial," of the superintendent to the defendant owner, for whom the house was built, should have been disclosed to the plaintiff contractor, and that under the circumstances the plaintiff was not bound to obtain the certificate required by the contract from the superintendent at all.

Ludlam v. Wilson, (1901) 2 O. L. R. 549.

This whole subject of the circumstances under which a contractor is dispensed from the necessity of procuring the final certificate called for by the contract was much discussed in a notable case in our own Courts some ten years ago, that of Conmee v. C. P. R., which lasted for seven years in the Courts with varying fortune to either party, judgment being given at the trial without a final certificate in favour of the contractors for upwards of a quarter million dollars, which was compromised for a much smaller amount after appeals to the Court of Appeal and Supreme Court.

Before proceeding to discuss some of the more recently decided cases to further illustrate these remarks, let me read a portion of one of the clauses (from the present form of contract used by the City of Toronto) constituting the engineer the sole judge:—

Z 20. "Should any discrepancies appear, or differences of "opinion or misunderstanding arise, as to the meaning of the Con- "tract or of the General Conditions, Specifications or Plans. or as

' to any omissions therefrom, or misstatements therein, in any "respect, or as to the quality or dimensions, or sufficiency of tne "materials, plant or work, or any part thereof, or as to the due "and proper execution of the works, or as to the measurement "or quantity or valuation of any works executed, or to be executed "under the contract, or as to extras thereupon, or deductions "therefrom, or as to any other questions or matters arising out of the "contract, the same shall be determined by the Engineer . . . "and his decision shall be final and binding upon all parties con- "cerned, and from it there shall be no appeal."

The result of many decided cases is the introduction into such contracts of many safeguards and restrictions drawn from wisdom learned by experience. Now, let us glance at a few of the judgments in which such similar provisions have been discussed by eminent Judges in England and Canada.

JACKSON V. BARRY RAILWAY COMPANY (1892), 1 Ch. Div. p. 258.

Arbitration—Unfitness of Arbitrator—Injunction—Jurisdiction.

A contract by which the plaintiff undertook to construct a dock for the defendant company, provided that any dispute between the company and the contractor as to the meaning of any part of the contract, or as to the quality or description of the materials to be used in the works, should be referred to the company's engineer as arbitrator. The dispute arose whether the contract required the interior of a certain embankment to be made of stone, or whether rocky marl was allowable, so that, if the contractor by the direction of the engineer used stone, he would be entitled to be paid for it as an extra. A correspondence took place between the contractor and the engineer, in which the engineer stated his view to be that the contract bound the contractor to use stone, and that it was not an extra. The company then referred the dispute to the arbitration of the engineer. After this reference, and on the day for which the first appointment had been made, the engineer wrote to the contractor a letter in which he repeated his former view. The plaintiff brought this action to restrain the company from proceeding further with the arbitration.

Kekewich, J., held that the last letter showed that the engineer had finally made up his mind on the point, and was, therefore, disqualified to act as arbitrator, and granted an injunction.

Held, on appeal, that, considering the position of the engineer who, as engineer of the company, must necessarily have already expressed an opinion on the point in dispute, his writing after the commencement of the arbitration a letter repeating the same opinion would not disqualify him from acting as arbitrator, unless, on the fair consideration of the letter, it appeared that he had made up his mind so as not to be open to change it upon argument:

Held by Lindley and Bowen, L.JJ. (Dissentiente A. L. Smith, L.J.), that the letter in question did not, upon its fair construction, show that the engineer had precluded himself from keeping his mind open, and that the injunction ought to be dissolved; and whether there was jurisdiction to grant it, quære.

Bowen, L.J.: It was an essential feature between the plaintiff and the railway company that a dispute such as that which has arisen between the plaintiff and the company's engineer should be finally decided not by a stranger or a wholly unbiassed person, but by the company's engineer himself. Technically the controversy is one between the plaintiff and the railway company; but virtually the engineer, on such an occasion, must be the judge, so to speak, in his own quarrel. Employers find it necessary in their own interests, it seems, to impose such terms on the contractors whose tenders they accept, and the contractors are willing in order that their tenders should be accepted, to be bound by such terms. It is no part of our duty to approach such curiously coloured contracts with a desire to upset them or to emancipate the contractor from the burden of a stipulation which, however onerous, it was worth his while to agree to bear. To do so would be to attempt to dictate to the commercial world the conditions under which it should carry on its business. To an adjudication in such a peculiar reference the engineer cannot be expected, nor was it intended, that he should come with a mind free from the human weakness of a preconceived opinion. The perfectly open judgment, the absence of all previously formed or pronounced views, which in an ordinary arbitrator are natural and to be looked for, neither party to the contract proposed to exact from the arbitrator of their choice. They knew well that he possibly or probably would be committed to a prior view of his own, and that he might not be impartial in the ordinary sense of the word. *What they relied on was his professional honour, his position, his intelligence*: and the contractor

certainly had a right to demand that whatever views the engineer might have formed, he would be ready to listen to argument, and, at the last moment, to determine as fairly as he could, after all had been said and heard. The question in the present appeal is, whether the engineer of the company has done anything to unfit himself to act, or render himself incapable of acting, not as an arbitrator without previously formed or even strong views, but as an honest judge of this very special and exceptional kind. I will assume (without deciding) what was assumed by both sides, in the argument at the bar, that the point before us is properly raised in such an action as the present, and consider the matter entirely on its merits. That the letter of the 2nd of August shows Mr. Barry to have had, and retained up to the opening of the arbitration, a rooted view that the contractor was wrong, is obvious. This, Mr. Barry may not have been able to avoid. Has he, then, disqualified himself from pursuing the function of such an arbitrator as the contract contemplates, by informing the contractor, in answer to the contractor's controversial letter, of what the contractor, I am convinced, well knew already, viz.: that Mr. Barry wholly disagreed with him? I cannot see that the letter of the 2nd of August warrants the inference that Mr. Barry would not or could no longer do his best, when the matter finally came before him and his legal assessor, to decide honestly between his own distinct view and that of the contractor. He restates, it is true, what he had already stated, and I daresay he thought it fair and honest towards the contractor to do so. I should agree with my brother Kekewich's judgment, if I thought the letter of the 2nd of August amounted to an intimation that the contractor would not be patiently listened to and receive at the last an honest decision. Where I differ from my brother Kekewich is, that he seems to me not to have made sufficient allowance for the very special character which by the contract this arbitrator had to fulfil, and to have required from the engineer of the company, who must necessarily be a somewhat biassed person, but by whose decision, nevertheless (fairly given), the parties had contracted to be bound—*the icy impartiality of a Rhadamanthus*. The difficulty in the contractor's way arises, not from the engineer's utterances in the letter of the 2nd of August, but from the fact that the contractor, by his contract, had pledged himself to submit this very dispute that has arisen to the person

with whom he virtually is waging it. The contractor is, as it appears to me, catching at a straw; endeavouring on the ground that the engineer had revealed a view which every one was aware he entertained, to escape from an onerous arbitration clause which the contractor accepted as part of the consideration for his bargain. To release him on such a pretext would be to dissolve his obligations under the contract and to substitute, by force of the power of this Court, *a wholly different and far more agreeable kind of arbitrament before either some stranger or a jury of strangers,* a tribunal which it was the express object of this contract to exclude.

For these reasons I differ from my brother Kekewich, with whose views as to the importance of judicial impartiality I entirely coincide, regarding them only as not quite applicable to this special case, in which it was part of the very bargain that the scales of justice in the case of a dispute need not be held in a neutral or wholly indifferent hand.

MCNAMEE V. TORONTO (1892), 24 O. R. 313.

By contract between contractor and city for additions and improvements to its waterworks system, all differences were referred to the award of one H., superintendent in charge of the waterworks.

Held that H., being superintendent, did not disqualify him from being arbitrator. and on the evidence no cause existed to restrain him from proceeding with arbitration:

Causes urged: H. furnished estimates of costs of work to city, which were acted upon in accepting plaintiff's tender unknown to plaintiff when he executed the contract.

Held, the fact that the superintendent signed certificate as to penalties to be deducted did not show he had prejudged the case.

Boyd, C.: The Scotch cases show that when arbitrator named is also engineer of works, anything he says or does falling within his ordinary functions as engineer does not disqualify him as arbitrator; this results from his dual character—in one relation acting as agent or representative of proprietors, and in the other changing his function to that of a judge who is to hear both sides before he decides the matter in dispute.

IVES AND BARKER V. WILLANS (1894), 2 Ch. 478.

An arbitration clause referring disputes to the engineer of one party cannot be disregarded on the ground that the engineer is in substance a judge in his own case, unless there is sufficient reason to suspect that he will act unfairly.

Provision: "If any question, difference or dispute shall arise between company and contractor touching the construction or meaning of anything contained in these presents or in said specifications, etc., or as to any works, plant, material, etc., which the company may require the contractor to do, or any extra work ordered or as to price to be charged, or moneys alleged to be due, or rights and liabilities of either parties, etc., the matter or difference shall be referred to the engineer, whose decision thereon will be final and conclusive on both parties."

Lindley, L.J., says:—"That is a very stringent provision and one is surprised at first that any contractor should submit to be bound so tightly, because a dispute between contractor and company is in substance a dispute between contractor and engineer, whose business it is to see that works are done for the company according to agreement, plans and specifications; and the real agreement between the contractor and company is that if there is any dispute between them, the engineer can tell the contractor what to do, and order him to do what he likes consistently with the agreement, his decision must be final."

The learned Judge gives two reasons. First: Competition for this kind of work is very keen and contractors compete with each other to get it. Second: It has been ascertained by long experience that *engineers of the highest character may be trusted,* and when a contractor enters into such a very stringent provision such as this he knows the man he has to deal with.

ECKERSLEY V. MERSEY DOCKS & HARBOR BOARD (1894), 2 Q. B. 66.

The rule which applies to a Judge or other person holding judicial office, viz., that he ought not to hear causes in which he might be suspected of a bias in favour of one of the parties, does not apply to an arbitrator named in a contract, to whom the parties have agreed to refer disputes which may arise between them under it. In order to justify the Court in saying that such an arbitrator is disqualified from acting, circumstances must be shown to exist

which established at least a probability that he will be in fact biassed in favour of one of the parties in giving his decision.

This was a dispute between the contractors and the board above named, in which the former claimed that by the negligence or incompetence of the assistant engineer, who was the son of the engineer under the contract, water had escaped into the Canada Dock which they were excavating, causing them delay and loss. The contractors commenced an action claiming it should not be stayed under arbitration clause, because of probability of bias of engineer in favour of defendants, and that engineer's son hoped to succeed his father in the post of engineer to board.

That eminent Judge, Lord Esher, said:—

"It seems to be admitted that if the engineer had to consider whether he had himself given a negligent or unskilful or incompetent order, it could not be said that the Court would be justified in directing that the matter would not be referred to him, but the Court is asked to act because such an order was given by his son; *i.e.*, a man who could not be biassed in judging of his own acts would be biassed to give a decision in favour of his son which he knew to be wrong. I cannot take that view of human nature."

"Where you have a man of high character, one whose character for impartiality cannot be impeached when he has to decide as to his own conduct, to say such a man would not have enough honesty and strength of mind to act impartially when his son's conduct came in question, is a statement which I cannot accept. I do not believe it in this particular case."

GOOD V. T. H. & B. R. CO. (1899), 26 A. R. 133.

The rule that a contractor is bound by a condition in his contract making the employer's engineer the interpreter of the contract and the arbiter of all disputes arising under it, does not extend to a case where a named engineer, while in fact the engineer of the employer, is described in the contract as, and is supposed by the contractor to be, the engineer of a third person.

In a contract between Good and a construction company, the engineer named was that of the railway company. The construction company in reality, though unknown to the contractor, controlled the railway company, and the engineer was really paid by them.

This was also unknown to the contractor. The final certificate was not given under the contract, but Armour, C.J., held that this did not disentitle the contractor from payment for his claim, the engineer being "Young's man from the beginning," Young formed the construction company, and the construction company controlled the railroad company. The learned Chief Justice said that the contractor was entitled to say upon discovering the arrangement between the engineer and construction company: "He is not our choice as judge under this contract, and we repudiate our being bound by the term of the contract which requires a certificate from him;" and Mr. Justice Osler held that the contractor had the right to assume that the engineer was not the servant or agent of the construction company, not their salaried official, that he owed no duty to them as having been employed by them, and that he was independent of them.

NOTES ON ALUMINUM CONDUCTORS.

F. C. Smallpeice, '98.

Since the earliest days of electrical engineering the superiority of copper as a conductor for commercial use has been undisputed. The high specific conductivity of copper (almost equal to that of silver), the ease with which it can be drawn into wires, and the high tensile strength of such wires, only exceeded by steel and iron, are properties which have rendered the metal invaluable for electrical purposes. In addition to this, the metal can be freed from its impurities, and a very uniform product obtained by comparatively inexpensive processes.

Within the last two or three years, however, the absolute rule of copper in the electrical world has been somewhat shaken by the rapid advances made in the manufacture of aluminum. Undoubtedly the abnormally high price of copper during the past three years has been largely instrumental in bringing to notice the claims of aluminum; and whether the latter will ultimately displace copper for some purposes is largely a matter of conjecture. Though but recently introduced, aluminum has been used for several long transmissions on this continent and in Europe, and great interest is being manifested in the results obtained on these lines.

Aluminum can hardly be said to have attained importance as a commercial product, or, at any rate, as a rival of copper, as the following figures will show:—

For the year 1900—

The world's output of aluminum was 6,150 tons, of which 2,225 tons were produced in the United States.

The output of copper for the same year was 543,000 tons, the United States producing 300,000 tons.

Thus the output of aluminum was only about 1.1% that of copper.

On this continent the only company manufacturing aluminum is the Pittsburg Reduction Company, operating works at Niagara Falls, N.Y., and at Shawinigan Falls, P.Q. During the past year or two this company has hardly been able to keep pace with the demand for its product.

In Europe there are six firms engaged in the reduction of aluminum from its ores, one of these being an English company. The methods employed are for the most part secret, but in all cases the process involves the use of electric current in a bath of fused electrolyte. It may also be said that all the European companies manufacture calcium carbide, though, of course, this is an entirely distinct branch of their business, the process being quite different from that of aluminum reduction.

The price of aluminum to-day is in the neighborhood of 30c. per lb., while the price of copper being controlled largely by trusts and subject to the trickery of the stock market, has in the last year ranged from 19c. to 12c. per lb. Considering the relative specific gravities and conductivities of the two metals for any given transmission, the weight of aluminum required is, roughly, half the weight of copper. Consequently at 30c. per lb. aluminum is equivalent to 15c. copper; and at 20c. per lb. would be as cheap as copper at 10c. Thus, though the aluminum industry is still young, the metal can to-day be put on the market at a price equivalent to that of copper as a conductor; and it seems probable that as their output increases the manufacturers will be able to produce the metal at still lower prices.

Specific Gravity.—Considering the properties of the two metals as affecting their use as conductors, we have first the specific gravity of chemically pure aluminum=2.56, while aluminum wire over 99% pure has a specific gravity of 2.68. This increased density in the com-

mercial wire is not proportional to the amounts of impurities present, but seems to be due to a contraction caused by these impurities, and depends also on the working of the metal. The specific gravity of commercial copper we may take as 8.93. Thus we get 1:3.33 as the ratio between the weights of equal volumes of aluminum and copper.

Tensile Strength.—Perhaps nothing has contributed so to the lack of confidence felt by many electrical men towards the new conductor as the failure, due to low tensile strength, of several of the first aluminum lines to be installed in this country.

When first introducing aluminum wire advantage was taken by the Pittsburg Reduction Co. of the fact that almost all foreign metals when alloyed with aluminum increase the tensile strength of the wire.

For instance, a No. 12 B. & S. wire showed a tensile strength of 39,000 pounds per square inch; same wire alloyed with 1% nickel, 45,000 pounds per square inch; same wire alloyed with 2% nickel, 55,000 pounds per square inch.

This increased tensile strength was not gained, however, without offsetting disadvantages. For, taking the conductivity of the pure aluminum as 63 in the Matthiessen standard, one per cent. of nickel reduced this to 58, while the two per cent. alloy showed a conductivity of only about 54. The above is the result of a test made by the Pittsburg Reduction Co.

For all the first lines installed alloyed wire was used, and the result was far from satisfactory. In almost every instance so many breaks occurred in the lines that they had to be replaced. In one instance over fifty breaks were reported in a mile of line, all occurring inside of one month. The cause of these failures seems to be a lack of homogeneity in the alloyed wires. Apparently the copper, nickel or other metal used to give strength to the wires does not form a perfect alloy with the aluminum, but tends to settle in spots in the wire bar. These spots are hard and brittle, and the wire is very apt to break at these points.

The use of alloyed wires has, however, been abandoned, and all wires sold at present are commercially pure aluminum. The results obtained have been very gratifying to the manufacturers.

The following figures are from tests made by the Pittsburg Reduction Co.:

	Elastic Limit	Ultimate Strength	Reduction in Area Per Cent.	Estimated Safe Working Load
Average of tests on wires $\frac{1}{2}''$ to $\frac{1}{8}''$ diameter (wire as drawn).........	12000	24500	58.46%	4500
Same annealed....................	10870	22830	65.57%	4500
Average of tests on wires $\frac{1}{16}''$ to $\frac{1}{30}''$ diameter........................	32000	54000	68.00%	12000
Same annealed....................	21000	33000	62.00%	7000

The tests were made on No. 1 quality aluminum, all over 98% pure. Annealing renders the wire more pliable, and more easily handled.

The practice of the company at present is to make all line conductors up in the form of cables. The reasons are two-fold. First, any weakness in one strand, due to hard spots caused by the concentration of impurities, does not endanger the whole cable. By stranding the conductor there is only a small chance of these brittle places coming together in the cable, and thus though one strand may be weak, the strength of the whole section will not be greatly affected. The second reason for stranding line conductors will be apparent by referring to the table just given. The higher tensile strength in the smaller size of wire is quite marked.

Up to No. 8 B. & S. 3-strand cables are used. For No. 6 B. & S. either 3 or 7 strands; and the number of strands is increased for sizes still larger.

Comparing the tensile strengths of copper and aluminum, Dr. Kennelly's tests for the Bay Counties Co. of California gave an average of 33,000 pds. per sq. in. as the ultimate strength of the aluminum wire used. The strength of soft drawn copper is given by Roebling as 32,000 to 36,000 pds. per sq. in., and 45,000 to 68,000 for hard drawn wire. In comparing, however, we must remember that for the same conductivity an aluminum conductor must have a cross-section 1.6 times that of copper.

The elastic limit of aluminum is not very well defined, for the reason that the wire takes up a permanent set at very low strains.

It appears, however, that somewhere between 14,500 and 17,000 (according to Dr. Perrine) this permanent set increases rapidly, indicating that the safe working load lies within these limits. In one respect this tendency to elongate is an advantage, since it counteracts to some extent the effect of the large co-efficient of expansion referred to later. For instance, a span drawn up in the summer, so as to allow but little sag, might break under the heavy strain due to the contraction in cold weather were it not for the stretching of the wire. It is necessary to exercise care in erecting aluminum spans to avoid reducing the cross-section in drawing up.

Under these conditions copper is much better, though soft-drawn wire has the same tendency. The percentage elongation in hard-drawn copper is very slight, but a loss of about 2% in conductivity can be counted upon, due to hard-drawing.

Expansion.—British Board of Trade gives the following figures:

Co-efficient of expansion (linear).

$$\left.\begin{array}{l}\text{Aluminum}\ldots\ldots\ldots\ldots 0.00001234.\\ \text{Copper}\ldots\ldots\ldots\ldots\ldots 0.00000887.\end{array}\right\}\text{ Per degree Fahrenheit.}$$

i.e., expansion of aluminum is 1.39 times that of copper.

Thus in climates subject to extremes of temperature greater care must be taken in erecting aluminum lines to give them the proper sag. In this connection rather complete tests have been made by the Pittsburg Reduction Co. to aid their customers in the erection of lines. In a span the sag at any given temperature cannot be computed from the co-efficient of expansion given above, since every increase in the length of the wire due to rise of temperature causes a decrease in the tension of the wire. Supposing the strain to be within the elastic limit, the decrease in tension causes a proportional decrease in length, so that it has been found that the net expansion is about one-half what it would be if the wire were supported throughout its whole length.

The method of determining the net expansion is as follows:—

Spans of different lengths are chosen and the wires fastened securely at one end. The other end runs over a knife edge to a spring balance. By a standard at the centre of the span the deflection is measured. The deflection being noted and also the corresponding tension, the wire is given more sag by allowing a length

corresponding to the linear expansion for any desired rise of temperature to pass over the knife edge. Then the deflection and tension are again noted. Thus the conditions of the wire over a wide range of temperature can be determined.

The table gives the results of a series of such tests.

TABLE OF DEFLECTIONS AND TENSIONS FOR ALUMINUM WIRE.

X = Deflection in inches at centre of span; S = Factor, which multiply by weight of foot of wire to obtain tension. Maximum Load = 15,000.

	t = −20° F		−10°		0°		10°		20°		30°	
Span	S	X	S	X	S	X	S	X	S	X	S	X
80	12940	$\frac{3}{4}$	1660	$5\frac{3}{4}$	1176	$8\frac{1}{8}$	961	10	833	$11\frac{1}{2}$	781	$12\frac{1}{8}$
100	12940	$1\frac{1}{8}$	2083	$7\frac{1}{4}$	1470	$10\frac{1}{4}$	1202	$12\frac{1}{2}$	1042	$14\frac{3}{8}$	933	16
120	12940	$1\frac{5}{8}$	2500	$8\frac{5}{8}$	1768	$12\frac{1}{4}$	1400	$15\frac{3}{8}$	1251	$17\frac{1}{4}$	1120	$19\frac{1}{4}$
150	12940	$2\frac{5}{8}$	3038	$11\frac{1}{8}$	2540	$14\frac{1}{2}$	1788	$18\frac{7}{8}$	1552	$21\frac{3}{4}$	1390	24
175	12940	$3\frac{1}{2}$	3643	$12\frac{5}{8}$	2576	$17\frac{7}{8}$	2104	$21\frac{3}{4}$	1822	$25\frac{1}{4}$	1630	$28\frac{1}{4}$
200	12940	$4\frac{5}{8}$	4206	$14\frac{1}{4}$	2947	$20\frac{3}{8}$	2403	$24\frac{7}{8}$	2084	$28\frac{3}{4}$	1930	$31\frac{1}{8}$

40°		50°		60°		70°		80°		90°	
S	X	S	X	S	X	S	X	S	X	S	X
680	$14\frac{1}{8}$	630	$15\frac{1}{4}$	589	$16\frac{3}{8}$	555	$17\frac{3}{8}$	527	$18\frac{1}{4}$	502	$19\frac{1}{8}$
869	$17\frac{3}{4}$	768	19	735	$20\frac{3}{8}$	695	$21\frac{1}{2}$	658	$22\frac{3}{4}$	628	$23\frac{7}{8}$
1022	$21\frac{1}{8}$	946	$22\frac{7}{8}$	885	$24\frac{3}{8}$	835	$25\frac{7}{8}$	792	$27\frac{1}{4}$	755	$28\frac{5}{8}$
1265	$26\frac{5}{8}$	1177	$28\frac{5}{8}$	1060	$30\frac{3}{8}$	1039	$32\frac{1}{2}$	987	$34\frac{1}{4}$	941	$35\frac{7}{8}$
1488	$30\frac{1}{8}$	1377	$33\frac{3}{8}$	1279	$35\frac{7}{8}$	1215	$37\frac{3}{4}$	1152	$39\frac{7}{8}$	1099	$41\frac{3}{4}$
1672	$35\frac{1}{4}$	1574	$38\frac{1}{4}$	1473	$40\frac{3}{4}$	1393	43	1316	$45\frac{1}{2}$	1256	$47\frac{3}{4}$

Electrical Properties.—The conductivity of the Pittsburg Reduction Co.'s wire has been given as between 60 and 61 in the Matthiessen scale, though within the last few months the writer understands that this has been increased to 62 through improved methods of treatment. Annealed copper averages a conductivity of 99, and $\frac{99}{62}=1.6$ is the ratio of the specific conductivities.

It will be remembered that in the B. & S. gauge this corresponds very closely to r^4, where r (1.12) is the ratio between the diameters of any two consecutive sizes. Thus a convenient rule for determining the equivalent of a copper wire of any

gauge number is to take the aluminum wire two sizes larger. For example, No. 00 copper has a conductivity equal to No. 0000 aluminum.

For equal conductivity in a given transmission the weights of copper and aluminum required will be as $1 : \frac{160}{335} = 1 : 0.48$.

Effects of Alternating Currents.—The self-induction and capacity of a transmission circuit depend upon the ratio of the diameter of the conductors to the distance between them. For the same conductivity the diameter of an aluminum wire is roughly 26% greater than that of a copper wire. Hence we can say:—

(*a*) If the aluminum wires are 26% farther apart than the copper wires, the capacity and self-induction will be the same.

(*b*) It can also be shown that if the wires be the same distance apart that the self-induction of the aluminum circuit will be decreased from 3 to 5%, and its capacity increased by about the same amount as compared with a copper circuit of the same conductivity.

Skin effect—or the tendency of an alternating current to flow near the surface of a conductor, thus increasing its effective resistance. This effect is almost always negligible with frequencies ordinarily employed in transmission work, the increase in effective resistance being only ½% for a ½-in. copper wire at 60 cycles. Skin effect is proportional to the square of the frequency and cross-section, and inversely proportional to the square of the specific resistance, hence for aluminum and copper wires of equal conductivity the effect is the same since the cross-section and specific resistance are increased in the same proportion.

From the above it would appear that so far as the effects of alternating currents are concerned, there is little to choose between aluminum and copper. Any difference in their behaviour is in favour of aluminum.

The temperature co-efficients of resistance are about the same, viz.:—Aluminum, .00214 per degree F.; copper, .00217 per degree F.

Chemical Properties.—When we consider the chemical properties of aluminum we are confronted with a serious difficulty, namely, the joint problem. With copper, good permanent joints equal in conductivity to the wire itself can readily be made by soldering, but the soldering of aluminum is such a difficult and uncertain operation that it is almost impossible to carry it out in line work.

This difficulty in soldering may be attributed to three causes:—

(1) Aluminum is very highly electro-positive, in fact more positive than any of the commercial metals. Consequently it oxidizes very readily, and its surface is always coated with a thin film of Al_2O_3, which has to be removed to effect a soldered joint. Ordinary fluxes have no effect, as the oxide film forms as fast as it is removed. The usual method employed is to use a solder of such a composition that it contains its own flux, and thus the removal of the oxide film and the "taking hold" of the solder are simultaneous.

(2) Owing to the high specific conductivity for heat of aluminum, it requires a very high temperature to effect a joint. Also while solder combines with copper at 460° F, over 650° F is required to make a combination with aluminum.

(3) The fact that aluminum is so highly electro-positive is the cause of galvanic action between the metal and its solder, unless the solder be very near aluminum in the electro-chemical series. A few days in water will render useless many an apparently good joint.

The solder recommended by the Pittsburg Reduction Co. is that proposed by Mr. Joseph Richards, and is also that used by nearly all the manufacturers of aluminum in Europe.

Its composition is:—29 parts tin,
11 parts zinc,
1 part aluminum,
1 part phosphor-tin.

The superiority of the solder seems to be due to the phosphor-tin. The parts are heated and the melting stick of solder rubbed hard over the surface to remove the film of oxide. While the solder is still fluid the surface is rubbed with a metal brush to ensure a thorough combination. After the pieces are tinned as above, pure block tin is used to sweat them together. As it is impossible to cause the solder to flow into an aluminum joint, the tin must be put just where it is required.

While the above process appears to be fairly simple, unless the work is done by an expert, the joints are seldom satisfactory. Consequently in nearly all lines recently erected mechanical joints have

been used, and as far as can be learned they have proved quite successful. Several forms of mechanical joints are given below:—

Fig. 1 is an aluminum sleeve employed for sizes up to No. 000. The ends of the wire are inserted and the whole is twisted through three or four turns. Fig. 2 is known as the compression joint, and consists of three parts. The cable ends are inserted in the sleeves 2 and 3, and held in place by hydraulic pressure. This is usually done in the factory, both ends of every coil sent out being furnished

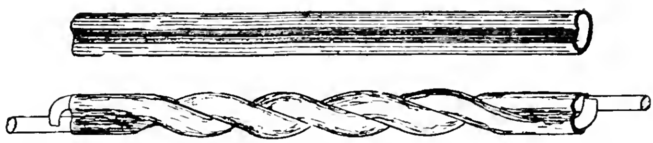


Fig. 1

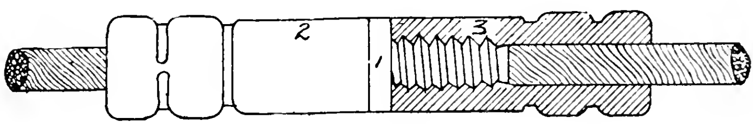


Fig. 2

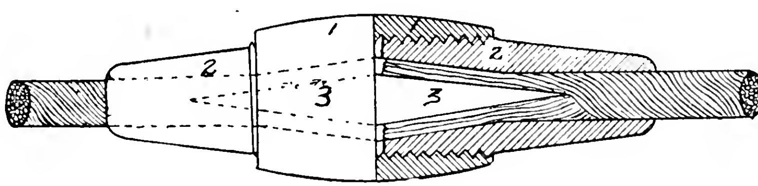


Fig 3

with sleeves; then all that is necessary in the erection of the line is to couple these sleeves together by means of the right and left hand connector 1. Fig. 3 is called the wedge joint. The ends of the cables are passed through the sleeves 2, and the strands spread by the conical wedges 3. The coupling 1 is now screwed on, and as the bases of the wedges are pressed together the wires are pressed more firmly against the conical recess in the sleeve. Both of the latter forms of joint are quite largely used, the compressive joint being the more common.

The action of gases and vapors upon aluminum wire is still rather a moot point. While the manufacturers claim that the metal is quite equal to copper in its non-corrosive properties, investigations of Kershaw in England show that the wire is corroded by the sulphurous vapors of a city and by hydrochloric acid. It is perhaps hardly fair to judge the American product by the results of Kershaw's tests, as his experiments were with heavily alloyed wire of 51% conductivity. It might be said also, that the tests were conducted at St. Helen's, which is the centre of large chemical industries. A less favourable place could hardly have been chosen. The action of hydrochloric acid is not as great as might be expected, protection being afforded by the coating of $Al_2 O_3$ which always covers the wire. The manufacturers claim that no corrosion takes place on wires exposed to the salt air along the coast.

The galvanic action of aluminum in contact with nearly all metals makes it important that all ties, joints, etc., be made of the same metal. The resistance to corrosion is decreased by small percentages of impurities, notably silicon and iron, which are difficult to remove. Sodium is also most harmful. The Pittsburg Reduction Co. attribute nearly all failures from corrosion to the presence of these metals.

To sum up what has been said, weight for weight aluminum has about double the conductivity of copper, with a tensile strength about 90% that of soft-drawn copper or 60% that of hard-drawn copper. The weakening tendency of impurities is overcome by the use of stranded conductors. It is possible to use longer spans for aluminum wire on account of its lightness.

On the new Niagara-Buffalo aluminum line the poles are 113 feet apart, against 75 ft. spans on the copper line. Thus a saving of about one-third on the poles and insulators was effected.

Chemically the balance seems to be in favour of copper, though the aluminum lines already in use have not been in position long enough to give any definite information on this point. The joint problem has been satisfactorily solved by the mechanical contrivances described. With aluminum we have reduced freights, and gain in the matter of distribution and handling. It is claimed also by those who have used aluminum, that the labour in erection is materially less than where copper is used. The wire can often be

strung along the ground and carried upon the poles on a man's shoulder. It is said also that the care necessary in giving the proper sag has been exaggerated.

Aluminum is not so well adapted for other branches of electrical work, except perhaps for bus bars, where it has been quite extensively used. The large cross-section, as compared with copper, makes its use for armature conductors and all windings where space is an important factor, almost prohibitive. It has replaced brass in the parts of many electrical measuring instruments, and has also been recommended for spacing blocks in iron cores. The large section makes insulation of aluminum conductors more expensive, and the finished wire is very bulky. Mr. Steinmetz says that aluminum has not proved successful for commutators. There are many other minor uses to which aluminum has been put, too numerous to mention here.

THE BEHAVIOUR OF STEEL UNDER STRESS.

PROFESSOR C. H. C. WRIGHT, B.A. SC.

While discussing with one of the members of the Council of this Association the results of certain experimental work of the post-graduate year at the School of Practical Science, I was induced to pr mise a paper on the behaviour of steel under stress, and in its preparation I have kept in view the younger members and students of the Association.

Inasmuch as the use of steel has completely revolutionized methods of construction and plan, its effect should be and is apparent in the design, not, however, to the extent the material deserves. It has been the custom for years to use rolled shapes, rivets, and joints of an engineering type partly because this branch of the work has been generally relegated to the engineer, and partly because most of the steel work is hidden. Is not much of it hidden because it is considered unsightly? Why should not the parts exposed to view be æsthetically treated and the shapes receive architectural attention.

It has always been considered necessary to study carefully the properties of other building materials. The successful treatment of granite shows boldness or vigor; of marble, delicacy or refinement; of sandstone, elaboration; of terra-cotta, repetition, etc.

While steel has been used very largely during the last decade, it will be used much more extensively in the immediate future. It becomes desirable that the members of our profession should, and imperative that the younger members shall, observe closely the peculiar properties and behaviour of this important material in order that it may be treated satisfactorily in design as well as in construction. It ought not and cannot be left to the engineer.

NOTE.—This is a paper read by Professor Wright before the Annual Convention in January, 1902, of the Ontario Association of Architects.—EDITOR.

Another difficulty that might be mentioned is the action of fire on steel. Serious as this difficulty is from the point of view of design, it must be met frankly and not forgotten that this very same property enables it to be rolled and worked into shapes economically.

Interesting as this line of thought is, we must turn our attention to the more elementary stages and consider a few of the properties of steel.

Suppose a steel rod (usually 24″ long) is placed in a testing machine and a load applied so as to produce tension in the rod. Now if measurements of the lengths of a part of the rod (usually 8″) are made, it will be found that for every load applied or stress induced there is a corresponding change in length, a deformation or strain; further, that when the load is removed the load will regain its original length.

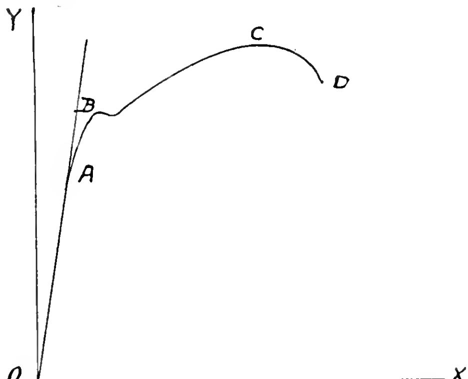
There is a point, however, beyond which this is not true, or where the deformation or strain is not constant for equal increments of load or stress. Below this point steel is elastic, while beyond it it is plastic. The point at which this change occurs is called the elastic limit. If, however, a piece of steel be stretched (strained) beyond the elastic limit, and the load removed, it will contract more or less, but will not regain its original length.

The measurements of deformation or strain, which must be accurate to the nearest 1-10,000 of an inch, are made with an extensometer of which this Riehle Yale represents a very satisfactory type. As will readily be seen, the points of the screws which fasten it to the specimen are held rigidly 8″ apart. After fastening it to the specimen, the bar connecting the two heads is removed, and the two micrometers are read or set at zero (the contact being determined by the ringing of an electric bell on the closing of the circuit by the contact). A load is next applied to the specimen, and the micrometers are again read, the difference between the two sets of readings giving the deformation or strain corresponding to the load or stress. If the stress be doubled the micrometers will show that the strain has been doubled. As the stress is increased it will be found that equal increments of load will produce equal strains so long as the steel remains elastic, or in other words within the elastic limit.

If these measurements were continued and the resultant stress strain curve drawn, plotting the loads as vertical ordinates, and the

strains as horizontal abscissa, it would resemble O A B C of the accompanying figure.

In the complete curve there are four significant points, viz., the true elastic limit, A; the apparent elastic limit, B; the ultimate strength, C; and the breaking point, D. From O to A the ratio of stress to strain or load to deformation is constant and the curve becomes a straight line. Between A and B the ratio of strain to stress increases slightly, while at B a very marked change takes place, hence the term "apparent elastic limit." Micrometer measurements of the length are not necessary to determine this point, and consequently it is widely used in commerce, and is often spoken of as "the commercial elastic limit," or often merely "elastic limit." Beyond the elastic limit the material continues to increase



Stress Strain Curve of Steel in Tension.

in length as additional loads are added until it reaches its ultimate strength, when it begins to fail. It no longer continues to support the load, but stretches under a decreasing load and finally separates under a greatly reduced one such as is indicated in our diagram by the point D.

Specimen No. 1 is a mild steel made by the open hearth process and gave the following results when tested in tension. The length of the specimen was 24 inches and its diameter 1″.015. Punch marks one inch apart were made along the rod. The specimen was then placed in the testing machine and subjected to tension. The load was gradually applied and the material elongated uniformly for a time until it reached a point where it stretched under

a constant load of 21,000 pounds, *i.e.*, the commercial elastic limit of $21{,}000 \div (1.015^2 \text{x}.7854)$ *i.e.*, 21,000 divided by the cross-section of the rod or 27,200 pounds per square inch. The rod finally broke under a load of 37,700 pounds or of $37{,}700 \div (1.015^2 \text{x}.7854)$ or 47,200 pounds per square inch of its original cross-sectional area. On measuring the distance between two of the punch marks originally 8″ apart (4 on each side of the break), it was found to be 11.08″ long, *i.e.* the steel had an elongation in 8″ of 38.5%. Collecting we have:—

Commercial elastic limit......................27,200 pds. per sq. in.
Ultimate strength...........................47,200 " "
Elongation in 8 inches.......................38.5%

The following measurements made on this specimen will show perhaps more clearly the elasticity of the material.

Load in Pds.	Stress in Pounds per sq. inch.	Extensometer readings.	Deformation or Strain.
1,000	1237	8.0005	0.0005
2,000	2474	8.0009	.0004
3,000	3711	8.00125	.00035
4,000	4948	8.00160	.00035
5,000	6185	8.00195	.00035
6,000	7422	8.00225	.0003
7,000	8659	8.0026	.00035
8,000	9896	8.00295	.00035
9,000	11133	8.00325	.0003
10,000	12370	8.00355	.0003
11,000	13607	8.0039	.00035
12,000	14844	8.00425	.00035
13,000	16081	8.00455	.0003
14,000	17318	8.0049	.0003
15,000	18555	8.0052	.00035
16,000	19792	8.00555	.0003

On drawing this stress strain curve, plotting the stresses as vertical ordinates and the strains or deformations as horizontal abscissæ, we get the following diagram.

The complete stress strain curve is given in Fig. 2.

Specimen No. 2 of Milo Steel, made by the open hearth process, gave the following results in tension:—

Length of specimen,.....................24 inches.
Diameter of specimen.................1.015 inches.
Apparent elastic limit..............27,000 pounds per square inch.
Ultimate strength,....................47,500 pounds per square inch.
Elongation in 8 inches,................38.0%

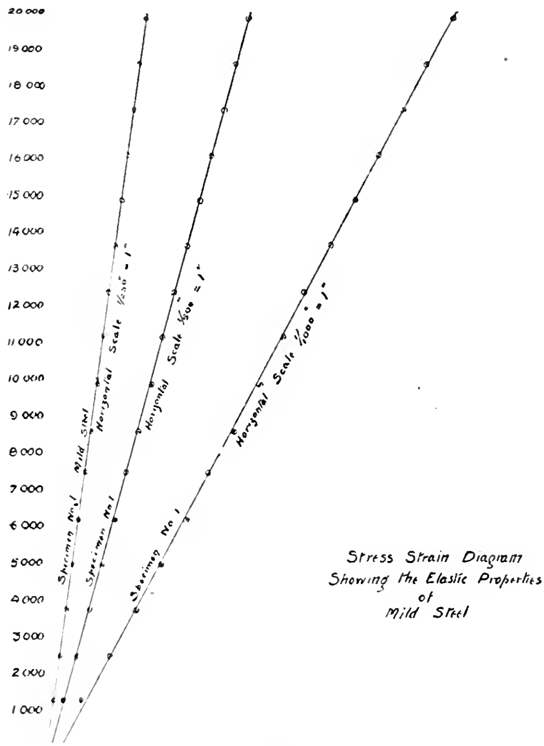


FIG. 1.

Load.	Stress in Pounds per Square Inch.	Extensometer Readings.	Elongation.
0	0	.27135	
1000	1237	.27185	.0005
2000	2474	.27235	.0010
3000	3711	.27265	.0013
4000	4948	.27290	.00155
5000	6185	.27325	.0019
6000	7422	.27355	.0022
7000	8659	.27395	.0026
8000	9896	.27430	.00295
9000	11133	.2746	.00325
10000	12370	.2749	.00355
11000	13607	.2753	.0039
12000	14844	.2756	.0043
13000	16081	.27585	.00455
14000	17318	.27655	.0049
15000	18555	.27655	.0052
16000	19792	.2769	.00555

Specimen No. 3 mild steel made by the Bessemer process gave the following results in tension:

Length of specimen.........................24″
Diameter of " 1.0155
Apparent elastic limit ....29,500 pds. per sq. in.
Ultimate strength ....46,400 " "
Elongation in 8″ 40%

Load.	Stress in pds. per sq. in.	Micrometer Readings.	Elongation.
		.5578	
1000	1229	.5581	.0003
2000	2457	.5586	.0008
3000	3685	.5591	.0013
4000	4914	.5595	.0017
5000	6145	.5599	.0021
6000	7371	.5602	.0024
7000	8600	.5606	.0028
8000	9828	.5609	.0031
9000	11050	.5612	.0034
10000	12290	.5616	.0038
11000	13510	.5620	.0042
12000	14740	.5624	.0046
13000	15970	.5627	.0049
14000	17200	.5629	.0051
15000	18430	.5632	.0054

Specimen No. 4 of machine steel gave the following results in tension:

Length of specimen .... 24 inches.
Diameter of specimen 1.014
Apparent elastic limit ....
Ultimate strength 100,600
Elongation in 8 inches............................. 16.5%

Load.	Stress in Pounds per Square Inch.	Extensometer Readings.	Elongation
1,000	1273	.3837	.
2,000	2547	.3840	.0003
3,000	3820	.3844	.0007
4,000	5093	.3848	.0011
5,000	6366	.3852	.0015
6,000	7640	.3856	.0019
7,000	8913	.3860	.0023
8,000	10190	.3864	.0027
9,000	11460	.3868	.0031
10,000	12730	.3872	.0035
11,000	14010	.3876	.0039
12,000	15280	.3879	.0042
13,000	16550	.3883	.0046
14,000	17830	.3887	.0050
15,000	19100	.3890	.0053
16,000	20370	.3394	.0057
17,000	21640	.3897	.0060
18,000	22920	.3901	.0064
19,000	24190	.3904	.0067
20,000	25470	.3908	.0071

Figure 3 is the stress strain diagram of specimens Nos. 2, 3 and 4 within the elastic limit. Allowing for reasonable errors of observation, the line joining the plotted points is a straight line showing conclusively that steel is within these limits perfectly elastic.

Before looking at the classification of steel, let us examine very briefly its composition and process of manufacture.

Cast iron, as you will remember, is a combination of from 2 to 6 per cent. of carbon with iron. The large amount of carbon determines its charasteristic features or behaviour. Wrought iron is the product resulting from the removal of carbon from cast iron. This leaves with the wrought iron such impurities as sulphur and

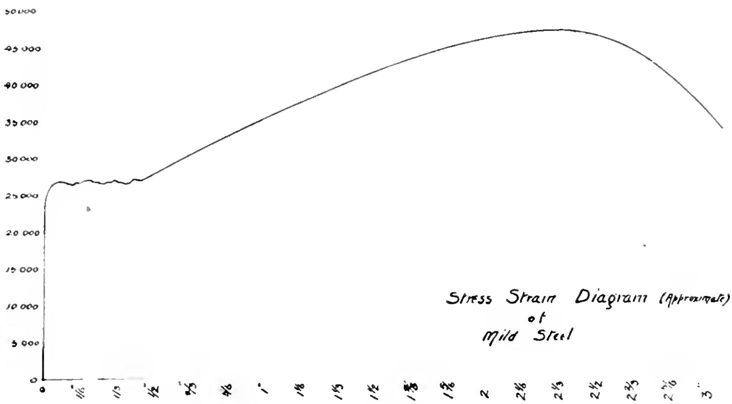


Fig. 2.

phosphorus. When these are present in too large quantities they render the iron red short or cold short respectively.

Steel is a combination of iron with a percentage of carbon varying from minute quantities to as high as 2%. It is manufactured in the three following ways, viz.—1. By adding carbon to wrought iron—the product of such process being known as crucible steel. 2. By removing carbon from cast iron—the product of this process being known as Bessemer steel. 3. By melting together cast and wrought iron—the product of this process being known as open hearth steel.

Cast iron is hard and brittle and can be moulded, while wrought iron is soft and ductile and can be welded. Steel is unlike wrought

iron in that it is fusible, and unlike cast iron, it can be forged, and with the exception of high grades, it can be welded. In addition to these advantages the higher grades can be hardened and tempered.

The term steel is applied to a class of materials which cover a very wide range of properties. One particular grade may be soft and ductile while another is quite hard and brittle. In tensile

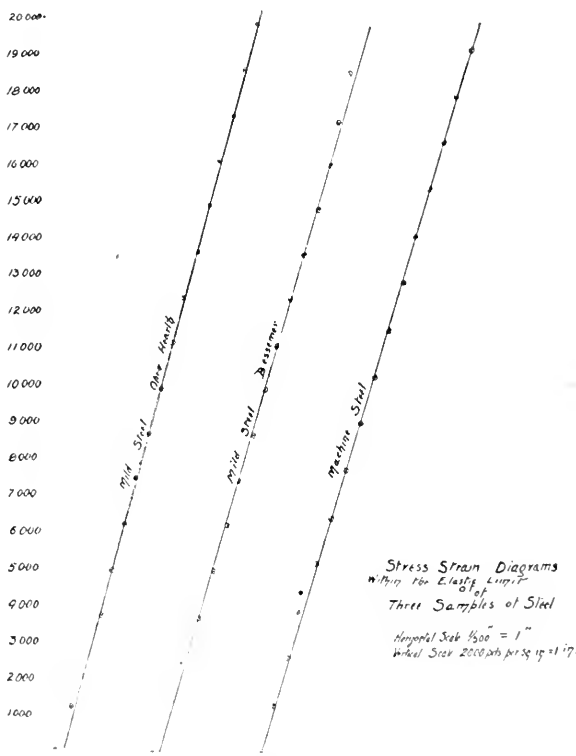


Fig. 3.

strength they may vary from 40,000 to 200,000 pounds per square inch.

It is now customary commercially to classify steels either according to their properties or uses. In the one group there is mild, medium or hard steel, while the other classification includes rivet steel, boiler plate, structural, machine, tool and spring steel, etc.

The following table gives a few of the characteristic physical properties of these different classes:—

Rivet steel should be ductile rather than strong and should have an ultimate strength of 40,000 to 55,000 pounds per square inch; elastic limit, 30,000 to 45,000 pounds per square inch; elongation in 8″ = 25 to 35%.

Boiler plate—Ultimate strength 50,000 to 65,000 pounds per square inch; elastic limit, 30,000 to 45,000 pounds per square inch; elongation in 8″ = 25 to 30%.

Structural steel—Mild, ultimate strength 40,000 to 55,000 pounds per square inch; elastic limit, 25,000 to 43,000 pounds per square inch; elongation in 8″ = 25 to 35%.

Medium—Ultimate strength, 55,000 to 70,000 pounds per square inch; elastic limit, 35,000 to 45,000 pounds per square inch; elongation in 8″ = 20 to 25%.

Machine steel—Ultimate strength, 80,000 to 110,000 pounds per square inch; elastic limit, 55,000 to 70,000 pounds per square inch; elongation in 8″.

Tool steel and spring steel—Ultimate strength, 120,000 to 200,000 pounds per square inch.

The standard specifications for structural steel proposed by a committee of the American Society of Civil Engineers in 1896 is as follows:

			Lbs per sq. in.
Tensile strength	low steel		60,000 + 4,000
"	"	medium	65,000 + 4,000
"	"	high	70,000 + 4,000

Elastic limit 55% of the ultimate strength of the specimen.

$$\text{Per cent. elongation in 8 in.} = \frac{1,500,000}{\text{Ultimate}}$$

$$\text{Per cent. reduction of area} = \frac{2,800,000}{\text{Ultimate}}$$

Rivet steel when heated to a low cherry-red and quenched in water at 82° Fahr., must bend to close contact without sign of fracture. Specimens of low steel when treated and tested in the same manner must stand bending 180° to a curve whose inner radius is equal to the thickness of the speimen, without sign of fracture.

Specimens of medium steel as cut from the bars or plates and without quenching, must stand bending 180° to an inner radius of $1\frac{1}{2}$ times the thickness of the specimen, without sign of fracture. While those of high steel, also without quenching, must stand bending 180° to a radius of twice the thickness of the specimen without sign of fracture.

In connection with the latter part of this specification, the following test may be interesting and instructive.

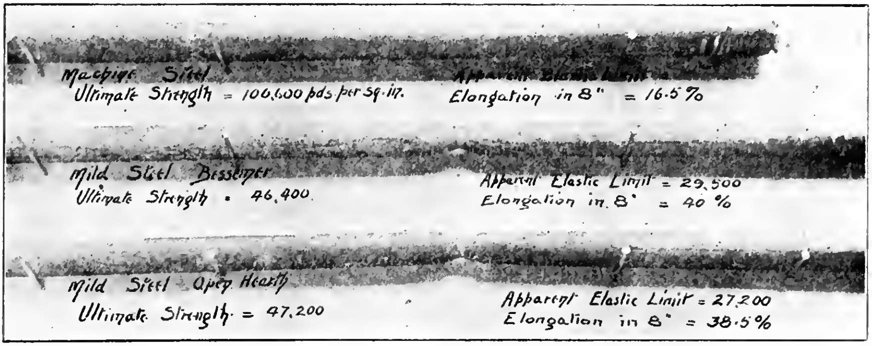
Two specimens, one of mild open hearth and the other of machine steel, were heated to a cherry-red, quenched with water and tested with the following results:

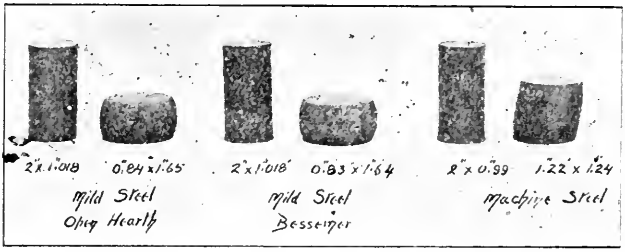
	Ultimate strength pds. per sq. in.	Elastic limit pds. per sq. in.	Elongation in. 8″
Mild steel	47,200	27,200	38.5%
Mild steel hardened	62,200	43,000	broke in strips
Machine steel	83,900	55,600	21%
do hardened	106,000	60,500	2%

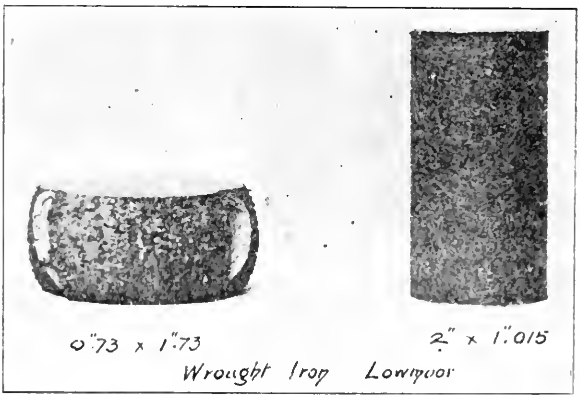
While almost every specification mentions maximum and minimum tensile strengths, it is very seldom that mention is ever made of the compressive strength, although the material is used quite as frequently in compression as in tension. This is because the ultimate strength, elastic limit and deformation or strain are more readily determined in tension than in compression, and because the results in tension are the same as those in compression.

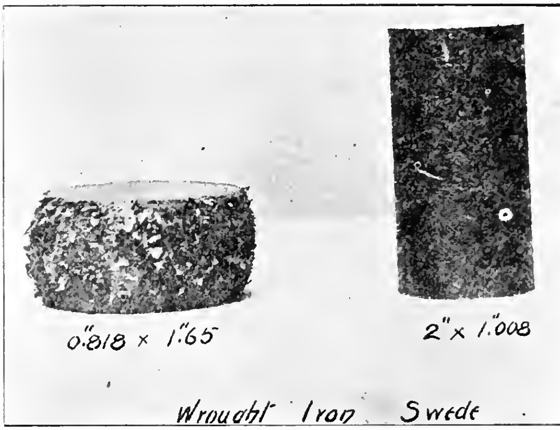
Under a uniformly increasing load steel in compression contracts uniformly within the elastic limit, which fortunately is the same as that for tension. When the load increases beyond the elastic limit the material simply spreads and increases the area of its cross-section indefinitely, so that in compression steel has no ultimate strength. This is well illustrated in the following specimens, originally 2 inches long, which were subjected to a load of 170,000 pounds each.

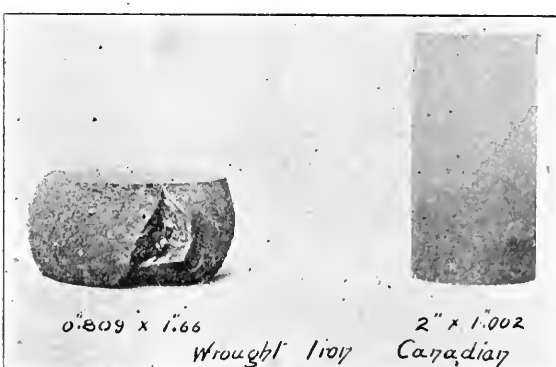
Specimens numbered 1, 2, and 3, are wrought iron, made in Sweden, England and Ontario respectively; while numbers 4, 5, and 6 are mild steel open hearth, mild steel Bessemer, and machine steel. Those specimens which are cracked open or are etched show very clearly the flow of the material under the stress.


Machine Steel
Ultimate Strength = 100,600 pds per sq. in.
Elongation in 8" = 16.5 %
Mild Steel Bessemer
Ultimate Strength • 46,400
Apparent Elastic Limit = 29,500
Elongation in 8" = 40 %
Mild Steel Open Hearth
Ultimate Strength = 47,200
Apparent Elastic Limit = 27,200
Elongation in 8" = 38.5 %


2" x 1".018
0".84 x 1".65
2" x 1".018
0".83 x 1".64
2" x 0".99
1".22 x 1".24
Mild Steel Open Hearth
Mild Steel Bessemer
Machine Steel


0".73 x 1".73
2" x 1".015
Wrought Iron Lowmoor


0"·818 × 1"·65
2" × 1"·008
Wrought Iron Swede


0"·809 × 1"·66
2" × 1"·002
Wrought Iron Canadian

The stress strain diagram for steel in compression when the stress is determined by dividing the load by the original cross-sectional area is as indicated in the annexed diagram, Fig. 4.

These compressive tests were made on a Riehle 200,000 pounds machine, and as the screws were kept running at a uniform rate, a

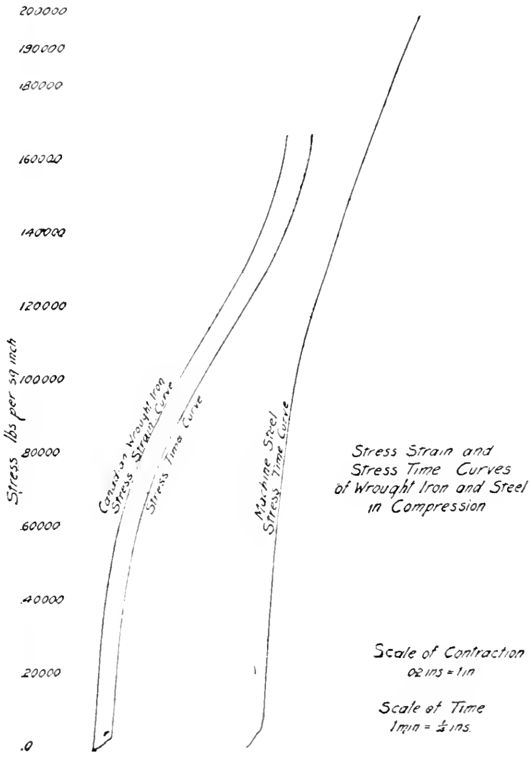


Fig. 4.

set of readings of the times required to produce the stresses were registered on a chronograph simultaneously with the measurements of the deformation or strain. On plotting from these results the stress strain curve and the stress time curve, it is found that they were identical when the scales correspond.

BRIDGE FOUNDATIONS AND ABUTMENTS.

J. HERBERT JACKSON, O.L.S., '03.

The information for the following paper was gathered last summer from work on which the writer was assistant in charge under C. H. Mitchell, C.E. It is intended as a descriptive paper, only such technical questions being taken up as are thought to be of interest to those unfamiliar with this class of construction.

The work comprised the building of two highway bridges to replace old ones over the Welland River, at points five and eight miles respectively above the town of Welland. The contractor undertook to remove the existent structures and erect others as per plans adopted. The cost of each bridge complete was $6,000. This included all work necessary to make the highway passable and ready for use by the public.

Looking at the problem from an engineering point of view, it resolved itself into designing a bridge for general highway use which would clear the stream in a single span. This length proved to be 134 feet from centre to centre of end pins. The approaches were to be earth embankments with the surface macadamized for a distance of 200 feet in each direction. The conditions of the soil, etc., on the sites of the bridges were found to be precisely similar, as was also the length of span, so that the two bridges could be built from practically the same set of plans. At the points selected the banks of the Welland are of a soft, black, porous earth on top of plastic clay, and in no way capable of sustaining a load except by piling for the foundations.

The stream is very sluggish, even running back on itself when the waters of the Niagara River are high. This seemed to comprise the total of the information at hand.

From these facts it was decided to put in a steel superstructure with abutments of concrete.

PILE DRIVING.

The question which now came up was the number, spacing, etc., of the piles, and was worked out as follows:—The bridge selected was one of 16 foot roadway and was to withstand a dead load of 600 lbs. per lineal foot, and a live load of 1,200 lbs. per lineal foot. The weight of bridge designed for these loads was 132 tons, or 61 tons weight to each abutment. The form of abutment gave a content of 90 cubic yards. This amount of concrete, at an average of 4,000 lbs. per cubic yard, made the weight of an abutment 180 tons. To this was added 36 tons for transferred earth pressure and miscellaneous load. Thus the load for each abutment was:—

Superstructure......	61 tons.
Content of abutment..........	180 tons.
Miscellaneous	36 tons.
Total..................	277 tons.

To support this it was thought that thirty-seven piles would be sufficient, and assuming the load to be uniformly distributed each pile had a load of 7.5 tons.

The formula for driving the piles was taken from the *Engineering News*.

$$L = \frac{2\,Wh}{S+1}.$$

Where L=safe load in lbs.

W=weight of hammer in lbs.

h=fall of hammer in feet.

S=penetration in inches at last blow.

In using this a factor of safety of 4 was assumed.

The safe load on each pile was then 7.5×4=30 tons=60,000 lbs.

The weight of hammer used was 2,600 lbs., and the fall was 30 feet.

To find S.

$$60000 = \frac{2 \times 2600 \times 30}{S+1} \text{ or } S = 1\ 6 \text{ inches.}$$

In the specifications, 1.5 inches was the maximum penetration allowed at the last blow.

In construction it was found that on both abutments of one of the bridges the centre piles gave a greater penetration than the

above, and it was necessary to add eight supplementary piles to each in order to come up to requirements. These were necessary by reason of the clay being much less solid than was anticipated from tests.

The addition of the eight piles made the strength ample for the weight to be sustained.

The driving of the piles was accomplished by sinking a coffer-dam about the space to be occupied and pumping out, when the usual method of drop hammer was used. The piles were banded to prevent brooming at the ends.

GRILLAGE AND PLATFORM.

On the top of piles sawed off true and level at two feet below low water mark was built a grillage of sound white oak timbers. These were 10 x 12 and had a full bearing on each pile and drift bolted with $\frac{3}{4}$-inch bolts with upset heads, driven flush. The grillage timbers supported a platform of white oak 5 inches thick. This was kept dry by the coffer-dam, which, being left in place, also acted as a protection after completion.

CONCRETE.

The concrete was laid on these platforms in molds built to the form of the abutment. The composition of the concrete for the interior of the abutments was in the proportion of 1 cement, 2.5 sand, 5 broken stone. The proportions for the weather surface to a depth of 6″ was 1 cement, 2 sand, 4 broken stone.

The forms for the concrete were held perfectly solid by means of rows of wires placed in at every three or four layers of concrete and fastened to the outside of the form. In this way, when one side of the form was made solid the other could not move. In removing these forms it was only necessary to cut the wires, leaving them in after trimming off the ends. All corners and angles were bevelled so as to give the finished abutment a neat appearance.

In mixing it was required that the cement and sand should be mixed dry and then water added. Finally the stone, which had been previously wetted, was added, and the whole thoroughly mixed.

This concrete was placed in 8″ layers; in placing the concrete in the forms the weather surface was mixed and thrown in close to the mold from the platform above. In this way the mass was pretty

well compacted on reaching its position. This was done all round the edge and raked to a comparatively even surface. The interior portion was now added to the height of the weather surface, and the whole was thoroughly tamped and compacted. Layer after layer was added in this manner till the whole was completed. Just at the surface, bridge-seats of limestone were set for the truss bearing of the superstructure.

Great care had to be exercised to keep the whole mass of each abutment from slightly moving out of alignment, and the forms had to be checked on permanent plugs set on the bank at some distance back. As a final precaution, when one abutment was complete the forms of the opposite one were checked on it so that if by any possibility it had shifted, the second one might be made parallel to it, and thus we avoided trouble when the steel work was to be set.

APPROACHES.

The approaches were built on an easy grade up to the bridge roadway and had side slopes of 1½ horizontal to 1 vertical. The surface was of limestone, well compacted, to form a solid pavement, and brought to a true grade.

The posts of the fencing along the sides of the approaches were prevented from leaning by a wire placed under the macadam and tightly twisted.

The superstructure was finally erected when the abutments were completed. To temporarily support this a net work of piles and false work was erected across the stream and removed again on the completion of the bridge.

THE COLLEGE GRADUATE AND HIS SPECIALTY.

C. H. Mitchell, B.A. Sc., C.E.

[The writer has been requested to prepare a paper on this subject in the hope that it may prove of service to students and graduates upon leaving college. The desire being to refer more particularly to Hydraulic Engineering, this specialty has been followed, but the general principles outlined would be quite applicable for other branches of the profession.]

Not until quite recent years has the true place of a scientific school begun to be assigned in the education of the young engineer. While a quarter of a century ago it was generally admitted that education in an engineering school was good, but not a necessity, it has come of late to be generally considered an indispensable factor in the education of the engineer. This is so, not only in Canada, but throughout all other countries, where, during the past few decades, the industrial activity has been very marked.

Previously the early education of the engineer, in whatever branch he might select, was planned out for him, leading through long terms of pupilage in engineer offices, gaining experience through the different steps of the work in the specialty or group of specialties to which he gave attention. The place of the school or college in this course of training was more to serve as providing the necessary foundation of general education, as distinguished from a scientific education, and the student was expected to derive his scientific attainment in a large measure from his experience and association with his comrades and superiors engaged in his engineering work, doing so by some means of absorption and example perhaps, more than by special devotion to study and research. The result of this has been the production of the famous engineers of experience who have brought us to the modern civilization, who have learned at nature's school, by nature's hand, by success and failure. These are the men who have enabled our modern schools to adapt the actual theory and the underlying scientific principles to the real work, its design, and construction.

Of latter years, however, the process of education has been different, and the school or college has taken a very prominent part. The school has supplied not only the general education, but the foundation, and, in some cases, a considerable portion of the techni-

cal education. Many of the leading schools have, of latter years, also provided a means of specializing in the engineering education, thus providing a means for the student to acquaint himself with not only the theoretical but also with much of the practical work of his chosen specialty. It does not follow, however, that the student graduating from a college in one of these engineering specialties can by any means be termed an expert, although there are some well known institutions which go so far as to lay claim to the distinction of graduating its students as "Engineers" in the full acceptation of the term. The writer believes that the principles laid down in connection with the School of Practical Science and Toronto University, with reference to the engineering courses, meet the modern conditions in an eminently satisfactory manner. The school does not pretend to do more than prepare the student in his theory and application of the theory, to teach him to study and pursue research, and, to a certain degree, "make him immediately useful when he commences actual professional work." Most engineering works, for the design and construction of which students are fitted, are such that their magnitude and general nature render it impossible to study them in such a manner as is possible to students in other professions. Many colleges meet this by arranging excursions and tours of inspection to interesting engineering works, either built or under construction. These, however, cannot be classed as anything but object lessons, and while valuable as such, do not permit of that close insight into methods and design of detail which would be so valuable to the young student. This applies primarily to engineering works of large magnitude, but almost equally so to works of easier access, particularly of a mechanical nature, because of the inability of the student to get to the true inwardness of the work in the short time usually at his disposal. The Toronto courses do not follow this plan, but prescribe a much better means by encouraging the student to employ his vacation periods in actual engineering service under what may be termed "actual working conditions," and in this way at once render him in touch with the professional life. Carrying this still further, he is told, after ordinary graduation, to go out into the professional world, having behind him his college or academic career with its primary scientific education, and its mere "elements" of preparation, and work with those who are designing and constructing, learning all he can as well as he can. After three years of this

active life under working conditions, he is told to come back with his record, and the University is then prepared to call him an Engineer.

The value of this programme of education is but partly appreciated by the under-graduate in his early days at the college, nor is it to be expected that he should see it as do the older and experienced engineers who have, perhaps, learned their work without the advantage of the college education. The young man, upon graduation, has learned many of the things which the early engineer learned after years of experience, and has probably become in a few years much more conversant with his theory and principles than the older man, but he has still to learn those things which the latter learned in his first six months. He has been taught to think and to reason, but he has yet to learn to work and to work hard, and incidentally to compute, design and superintend, to meet emergency, to become a friend and a master of nature and her laws, and above all, to know men.

It is upon graduation that specialization usually manifests itself, although in the college course the election of studies may have already determined it. However, in most cases the nature of the first few years out of college has all to do with the future line of work and may be considered to mould the taste or the talent of the graduate to this particular direction. It is at this time, perhaps, more than at any other, that this adaptability of the student to a particular line of engineering becomes apparent. All the professions have of recent years tended towards a division into specialties and the modern life is made up of the work of the expert to such an extent that even specialists employ other specialists on their work. This is equally true of the engineering profession, and on all large works the designers and constructors are, in reality, a group or staff of experts in the several departments.

Some specialists have for many years formed distinct branches of engineering, and many of these have of late again been subdivided into others, each having its followers. That of hydraulic engineering has existed for many years and has passed through many phases of interpretation. New lines of work have been added to it, and others have been removed, as for instance, that of sewerage, drainage, water works construction, etc., which are now usually classed with sanitary or municipal engineering, a new group. Of late years, and

particularly during the past decade, hydraulic engineering held a somewhat unique position and has consequently come to mean not only canal, river and harbour construction, with kindred works, as before, but water power development in all its branches. In the latter, such work in turn frequently calls for the employment of many other experts or special specialists, comprising mechanical, electrical, architectural, mining and sometimes chemical engineers in the varied classes of work required in water power construction for different purposes.

It is manifestly impossible, therefore, for the young graduate who desires to enter the field of hydraulic engineering, having in view the specialty of water power construction, to take it up as a single study in the same manner as one would many other lines. It is further evident that he must immediately upon leaving college, seek employment on works which will quickly put him in touch with this branch of the work. In this department of engineering, perhaps more than any other, should the student follow the school of experience, outlined as being that in vogue before the days of the science school. It is only in this method of getting out into the actual work, that hydraulic engineering can be studied, for the dearth of literature upon the subject is very marked. Water power engineering in reality is a very new line, and previous to, say, twenty-five years ago, it was studied by scientific men to but a small extent. No doubt the perfecting of long distance electric transmission has, within recent years, brought the whole question very strongly before the engineering profession, and electricity and hydraulic work are now destined to be grouped definitely together. Owing to the recent growth of this branch, the literature on water power questions is nearly all in magazine and periodical form, while the manufacturers of machinery are adding quickly to it by advertising matter, in the form of experimental research.

The writer would advise graduates of the School of Practical Science, desirous of following this line, to obtain employment in, or at any rate to visit and carefully examine designs, methods of construction and operation at water power centres, not only in Canada and the United States, but if possible in Europe. America, while not in the lead in research in this branch of engineering, is doubtless destined to become essentially a water power or hydro-electric power using continent. Already hydraulic enterprise is far beyond that of the

old world, and Canada, on account of her vast power resource, is not to be by any means behind in this progress. It is to Switzerland, Italy and Germany, however, that even yet we have to look for the lead in real scientific work, particularly under high heads. Nearer at home, however, the student should be acquainted with the characteristics of the rivers, watersheds, falls, and physical features, the methods of development, the conditions of operation and maintenance, and of the available markets for power generated, existing in the locality of each power centre. Grouped roughly, these centres might be said to comprise, in Canada: British Columbia, New Ontario, the "Soo," Niagara Falls, St Lawrence and Ottawa, Quebec, and as yet, to a small extent, several centres in the Maritime Provinces. In the United States are Massachusetts and Connecticut, which are probably pioneers, New York State, with Niagara Falls and the Adirondacks, Minneapolis, Colorado, Montana and California, where the boldest transmission work has been attempted, and a few scattered centres in the south. All of these have their own distinct features, and each forms a special study in problems of high or low heads, large units, floods, ice, and cold weather conditions, transmission or peculiarity of use.

The course to be followed by a student is plainly to gain experience by close association with power construction in several of these centres, and particularly in the designing and erection of new propositions if possible. The graduate from college could expect to first obtain employment at tracing, or other subordinate work at which he must some time start, and if ability is displayed, it will be but a short time before he may assist in design of details, or if his inclinations are such, he may get "out on the work" as a field man or superintendent of construction. From this work his real experience will date, and his value as a specialist increase with time. If he applies himself to become thoroughly acquainted with all the details of the work from design to operation, he should become very valuable in his one branch, commanding high remuneration, and not requiring to seek his employment.

To conclude, there is but one school, and that is experience, and but one master, and that is nature. The student, though he be first man in his year at college, must expect to start the humblest scholar, but after, with opportunity and energy, he may hope to earn rapid promotion with golden opinions for himself and his work.

THE HYDRAULIC LIFT LOCK ON THE TRENT CANAL AT PETERBOROUGH.

WALTER J. FRANCIS, C.E., M. CAN. SOC. C. E., ASSOC. M. AM. SOC. C. E., DIVISION ENGINEER, TRENT CANAL.

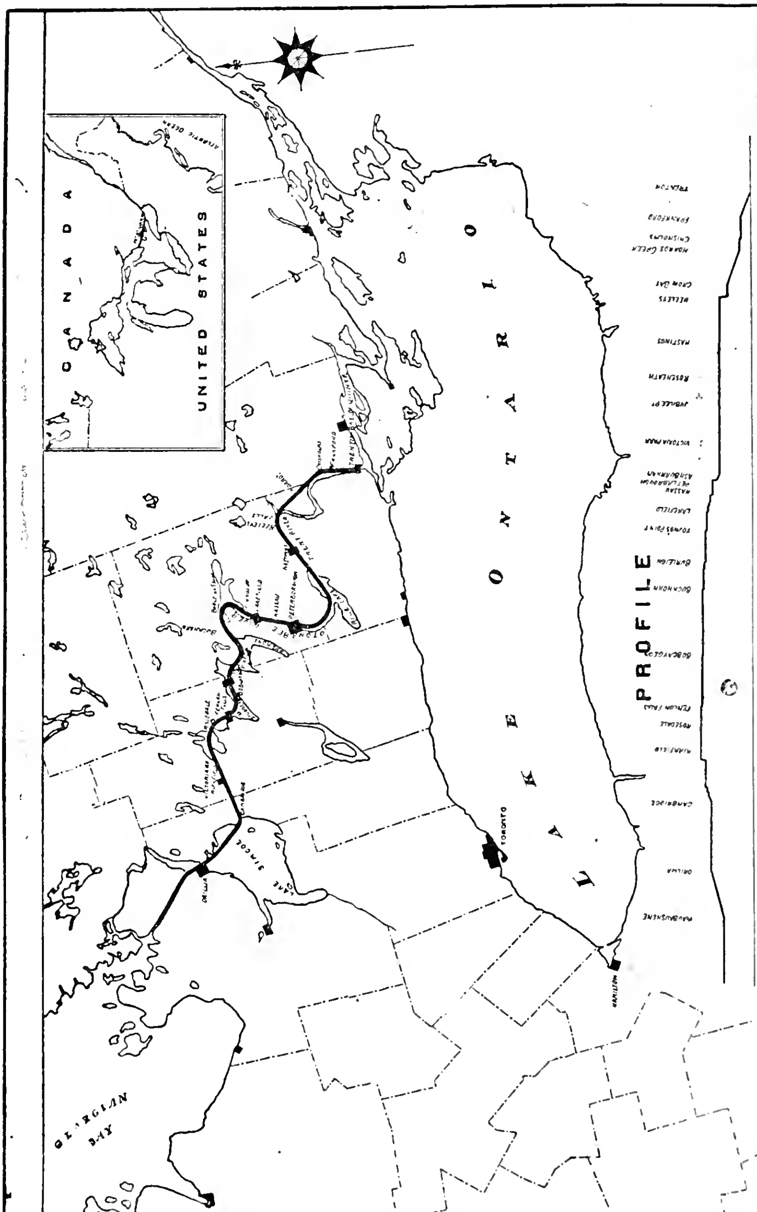
[The courtesy of Richard B. Rogers, Esq., M. Inst. C. E., M. Can. Soc. C.E., Chief Engineer of the Trent Canal, in kindly permitting the writing of this paper, is thankfully acknowledged by the writer.]

PRELIMINARY.

The hydraulic lift lock on the Trent Canal has been considered worthy of a special paper owing to the fact that it is not only the only one of its kind on the American continent, but also because it surpasses in capacity and in height of lift anything of its type that has hitherto been attempted.

In order to get a clear idea of the route on which this lock is being constructed, it might be well to state that the Trent water-way consists of a series of rivers and lakes connected by artificial canals. It is intended to form a connecting link between the southern end of Georgian Bay, at Midland Harbour, and Trenton, on the Bay of Quinte, leading to Lake Ontario. This canal, which has been under contemplation for a great number of years, and which was originally selected by the Royal Engineers of England as the most practicable route between the upper lakes and the sea board, is now being expeditiously pushed forward by the Government of the Dominion of Canada, and several contracts have been let and many of them completed during the last six years. Of the the total length of 203 miles, only about 33 require to be completed to furnish navigation throughout the whole distance.

Leaving Midland Harbour, where there is a depth of water of about 20 feet, the route is intended to pass by way of the River Severn into Lake Simcoe, this part of it as yet having had no work



MAP OF THE ROUTE OF THE TRENT CANAL.

done on it. From Lake Simcoe, through the valley of the Talbot River, Balsam Lake is reached, and from here access is had to a chain of magnificent lakes, many of which equal in grandeur of scenery the Thousand Islands. Leaving this chain of lakes the route enters the River Otonabee, which is better known at its lower end as the Trent, passing through the town of Peterborough into Rice Lake and thence to the Bay of Quinte. The whole of the route passes through a fertile and progressive part of the Province, and, from a local point of view, will be of immense benefit to the inhabitants of these parts. Many towns of considerable size and importance are located along the route. The chief importance of the water-way, however, is thought to be its value for barge navigation, permitting grain from the west to be brought in large vessels into Midland Harbour, here breaking bulk and unloading it into barges, which will be towed in lines of from two to six through this route down the St. Lawrence, to the ocean vessels in Montreal.

The works of the canal are being constructed in the most substantial and modern manner. The locks, with the exception of three, are of the ordinary type, and built entirely of concrete; some of them are said to have been the first of the kind in Canada. All the bridges are of steel, and very little timber is used in any structure above water level; so the entire work is carried out with the idea of complete permanency. The hydraulic lock, with which we chiefly deal, is located in a section of four miles of the canal which is built to overcome the obstructions to navigation found in the River Otonabee where it passes the town of Peterborough and where there are many water powers in use for manufacturing purposes. The total difference in elevation in this section is 77 feet. After leaving the river at the upper end about three miles and a half of canal is formed by short lengths of excavation and natural valleys until a slope of a hill is reached, where a difference in elevation of 65 feet is found in a distance of about 800 feet. Here the hydraulic lock is located and the difference in height overcome in one lockage. About a quarter of a mile further along the route has been built a lock of the ordinary type, which leads again into the natural water.

The hydraulic lift lock is, theoretically, an automatic machine, and is devised to take the place of the ordinary lock, where great differences in elevation are found in a comparatively short distance.

The first lock of this type was built by the inventor, Mr. Edwin Clark, of Clark & Standfield, Hydraulic Engineers, London, England, about the year 1872, in England, at Anderton, on the River Weaver, to connect the Trent and Mersey canals. While it differs somewhat in some particulars from the two other locks since constructed, it has answered its purpose admirably and has given no trouble. The same gentleman has also built, or has been connected with the building of, a lock of much larger dimensions at Les Fontinettes, in France, and at La Louviere, in Belgium. The Belgian Government has at present in some stage of construction four other locks of the same type. The chief dimensions of the Anderton lock are: lift, 50 feet; length of chambers, 75 feet; width, 15½ feet. The two locks already built on the continent, as well as those contemplated, have a lift of about 50 feet, with chambers 140 feet long, 19 feet wide, with 7 feet 10 inches normal depth of water.

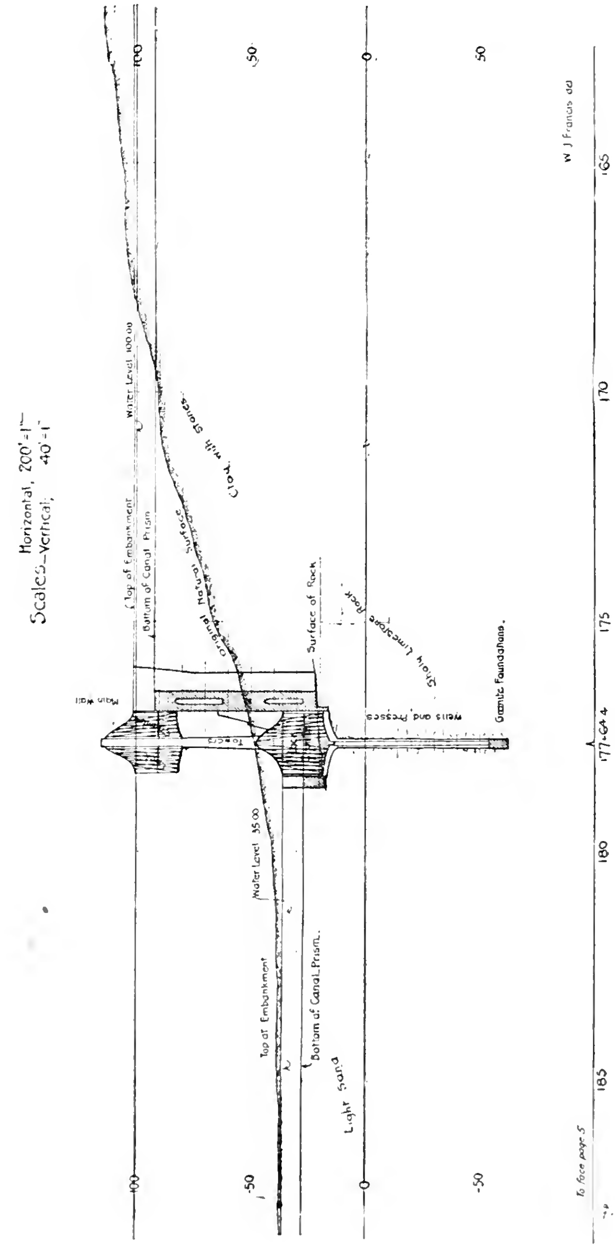
With this contrivance a lockage is performed by the vessel floating into a box or tank of water which can be shut off from the adjacent reach. The box, with the water and the floating vessel, is then raised or lowered to the other reach, with which communication can also be made. The power required to control the lowering, or to accomplish the raising, is obtained by having a similar box connected with the other and balancing it. Each of the boxes is carried on the top of a ram working in a hydraulic press. The two presses are filled with water and are connected by a pipe. The rams are arranged so that when one is up the other is down. The uppermost box is made heavier than the other. When a valve on the connecting pipe is opened the heavier box in descending forces down its ram, displacing the water from its press into the other press, making the ram protrude and carrying the lighter box up with it.

The manner of constructing the Canadian lock varies materially from those already built in about the same way that American practice varies from European, and so far as outward appearance is concerned, when the present work is finished, there will be little similarity, although the principles necessarily remain the same.

THE SUBSTRUCTURE.

As has been stated, the lock is located on a gradual slope. The excavation was begun in 1896. The exact point of location was chosen so that an average depth of excavation of about 40 feet was

PROFILE, shewing location of Hydraulic Lift Lock



required, and the material thus obtained was used in forming embankment to complete the length of the upper reach. The remainder of the material required to finish this embankment was obtained from the earth cutting above the lock.

The excavated material was found to be of a hard clay mixed with small stones and boulders underlying a thin layer of fertile soil. At the northern end of the excavation, where it was a little the deeper, a small amount of hard-pan was encountered, and below this a shaly lime-stone rock. This rock was in layers of from half an inch to eight inches in thickness, between which were thinner layers of clayey and shaly material. The layers of rock, which are of crystalline structure, stand the weather very well, but the shaly parts disintegrate very rapidly under the action of rain and frost.

The elevation at which this rock was found proved to be an exceedingly fortunate one, requiring as it did very little expensive excavation, and at the same time providing an excellent foundation for the heavy substructure and saving much concrete that would otherwise have been required for footings. It might also be added that the discovery of the rock was a pleasant surprise, as many common wells had been sunk in the neighbourhood to considerable depths without having encountered rock, and the borings made on the site had not been sufficiently extensive to discover it. The preliminary plans were prepared for establishing the substructure on earth. Before the work had progressed to any extent, however, extensive borings were made to determine the character of the underlying strata, in order that the contract for the wells, in which the large presses stand, might be let with some degree of certainty. One of the borings was made by a small horse-power machine to a depth of about 130 feet below the surface of the ground, and accurate notes, which have proven themselves correct in the work which has since been completed, were made as the borings progressed. The rock was also a decided advantage for the construction of the wells, which were about 80 feet deep. Its nature permitted it to be blasted and excavated with comparative ease, and no difficulty whatever was experienced in making an excellent job of the excavation at a very small cost.

The foundations in the wells require, as will be seen from what has been already said concerning the principle of the operation of the lift, that the utmost care be exercised in order that there shall

be no failure at this place, the total weight of the lock chamber, with its burden, having to be supported on the comparatively small base which the well affords. Here again the rock proved of great value. The total load at the bottom of the presses is, in round numbers, 2,000 tons, a rather heavy load to trust on so small an area of ordinary masonry foundation, and very much more than was considered advisable to put upon the somewhat poor quality of limestone found in the bottoms. On account of this rather excessive load and its uneven distribution at the press base, it was decided to use blocks of granite so arranged as to distribute the pressure uniformly over a sufficient area of the natural rock to give a bearing which seemed favourable under the conditions, and further, in order that not the slightest risk should be run in incurring possible accident and consequently enormous expense, these foundations were dealt with liberally and more expensive stones were used than would probably be called for under other circumstances.

The courses of granite were specified to be between 24 and 30 inches in thickness, and some of the stones were 7 feet 6 inches square, giving a weight (about 11 tons) requiring care in handling, and affording no little difficulties in the way of setting at such a great depth below the surface. Three courses of granite have been laid and finished in the wells and a very satisfactory job has been made. The design of these foundations will be seen by reference to the drawing on page 131.

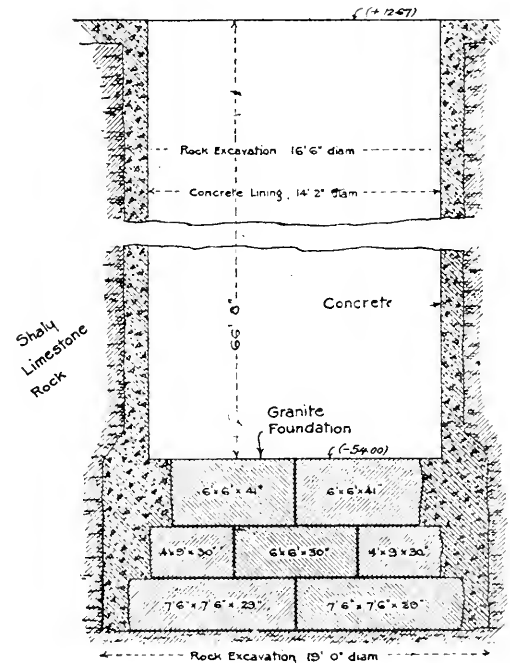
The walls of the wells are very regular and reflect credit on the man in charge of the work. By judicious arrangement of the charges of dynamite and blasting very little divergence was made from the truly cylindrical form, 16 feet 6 inches in diameter, which was required by the specification. It was decided, in order to prevent the disintegration of the walls of the wells, to line the sides with concrete. The thickness of the lining is sufficient to form a finished diameter of 14 feet 2 inches, in this way leaving a clearance all round the main presses of 3 feet. It is not necessary that this lining be water tight, although it is believed that it is practically so, as the wells will be constantly full of water and will require to be unwatered at intervals of perhaps five years for inspection purposes. Adequate means in the way of pumps are afforded for this purpose. In putting these linings in, the water was permitted to follow up the concrete work, thus relieving the pressure of any leaks through the

rock on the tender mortar by balancing it. This lining is carried up to the top of the wells and is finished at the floor of the lock-chamber pit.

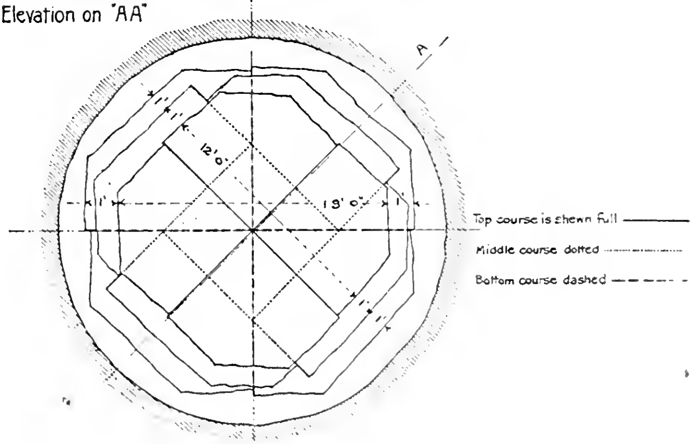
The substructure of the lock is built entirely of concrete and contains about 26,000 cubic yards. Of this amount some 25,000 cubic yards are already placed. The work has been carried out according to the working general plans which accompany this paper, and which have the special title "Masonry" and are numbered 1 to 10. The substructure may be divided for convenience into (a) main or breast wall, which serves the purpose of a retaining wall for the upper reach; (b) the wings, that further act as retaining walls in holding the side embankments, which will be seen by reference to plan; (c) the side walls, which form retaining walls for the earth along the sides of the lock; (d) the towers, the duty of which is to maintain the lock chambers in their vertical motion; and (e) the lower gateways which end the lower reach. All the walls (excepting the wings) form a dry pit, or rather two dry pits, into which the metal lock-chambers descend.

The main wall is 40 feet in thickness and about 80 feet in height; the length being 126 feet at the base. At about 15 feet from the rock surface there is formed for convenience a chamber or room, which is called the pump room, in which the turbines and pumps are installed. This room is 12 feet wide, 17 feet high and 110 feet long, including partitions 8 feet in thickness, which are intended to assist in taking the shear through the otherwise weakened cross-section of the wall. At about the original natural surface of the ground the wall is pierced longitudinally by a roadway, which will form a continuation of the line of the main street running through the town of Peterborough, giving access for vehicles to the furthermost side of the canal and dispensing with the ordinary swing bridge. This roadway is 14 feet wide and 21 feet high. In the top part of the wall are formed recesses for the gates which close the ends of the upper reach. Access is provided from the pump room to the roadway by a staircase formed in the concrete wall, and one may also pass from the roadway to the upper level by a spiral iron staircase placed in a cylindrical void formed in the concrete. Viewed from the side nothing of the main wall will appear below the level of the roadway. On this elevation an attempt has

PRESS WELLS — Scale, $\frac{1}{5}$"=1'.



Sectional Elevation on "AA"



Plan of Granite Foundation

been made to obtain an architectural effect by mouldings and pilasters.

The wings are situated, as will be seen from the plans, at the uppermost side of the main wall, extending 55 feet beyond it. Their form may best be seen by reference to the plans. They are carried down to the rock bottom in order that there may be no undue settlement between the main wall and the wings to cause unsightly cracks on the face and awkward breaks on the top surface. At the bottom the wings are only 40 feet in length, the full 55 feet being made up by cantilevering out 15 feet at the elevation of about 47 feet above the rock level. Considering also the light duty which these walls are called upon to perform, they have been made cellular in construction. Along their outer sides a stairway is carried up as a mean of access from the roadway level to that of the upper reach, and the mouldings of the main wall are continued along the exposed sides of the wings. The side elevation will convey very little idea of the differences in construction of these two parts of the work,—the main wall and the wings.

The side walls, as it has been said, form retaining walls for the earth along the sides and are intended to maintain the lock-chamber pits perfectly dry. These walls are of solid section and present no especial features. At the points next the main wall stairways are carried up from the level of the lower reach to that of the roadway as a convenient means of access from one to the other, and also to provide a sort of buttress to the main wall. In the term, side-walls, is included a wall 12 feet in width extending along the central line of the construction and dividing one pit from the other.

The towers, three in number, are located on the same transverse centre line as the two wells. In round numbers the total height of each from rock bottom to the top is 100 feet. Each of the side towers has a base 29′ 6″ x 40′ 8″, which decreases somewhat at the elevation of the top of the side walls. From this upwards the base of the tower is battered for a continual height of 45 feet; and above this the shaft on all sides is vertical 18′ x 18′ 6″. For operating purposes it is necessary to build the inside face of the tower plumb from top to bottom. The central tower has for the same reason to be plumb on both the sides next the chamber, while its other two sides conform to the same lines as those of the side

towers. Its width throughout is 12 feet. The towers have been treated in the same architectural manner as the main wall.

The lower gateways extend from the rock to the top of the side walls, and are formed to accommodate the steel gates which close the ends of the lower reach. In the centre between the gates is a small chamber which contains the hydraulic engine used to operate the gates.

It will be seen by referring to the masonry plans, for instance No. 3, that the concrete work is built in sections—the main wall stands by itself, being separated in construction from the side walls. In the same way the towers are not bonded with the adjacent side walls excepting in a lateral direction, by what is termed on the works a "key." The object of this system of construction is to obviate unsightly cracks, which occur from uneven loading on the foundation, as well as from contraction and expansion due to the extreme changes of temperature. It has been found in concrete work if lines of weakness are not provided in construction they form themselves in a short period of time. These lines of weakness are formed by placing a partition or "bulkhead" from face to back of the moulding of the wall, and keeping the concrete work on one side of it a few feet higher than the other. Before the lower side is brought up the bulkhead is removed and the new concrete is placed against that formed by the bulkhead. The vertical line thus formed is marked by a small triangular piece of wood 3-8" on a side, tacked to the face forming and which is removed with the forming. These vertical lines are never noticed on the walls, whereas a crack is commented upon by nearly everybody. Where the construction has to provide against unwatering and keep the water from leaking through from the back, the keys above referred to are introduced.

The concrete of the hydraulic lock goes under the general specifications for concrete used on this section of the canal. By the specification the concrete has to be formed of clean sharp sand, gravel, approved field stone broken to about 2-inch cubes, clean water and Portland cement. The cement is provided by the Government.

The cement used is Portland of the best quality. About ninety-five per cent. of that used was of Canadian manufacture. About five thousand barrels of German Portland, which proved to

be of excellent quality, were also used. The Government maintains an excellent cement laboratory, with an efficient chemist in charge, where all the cement undergoes rigid examination before it is used.

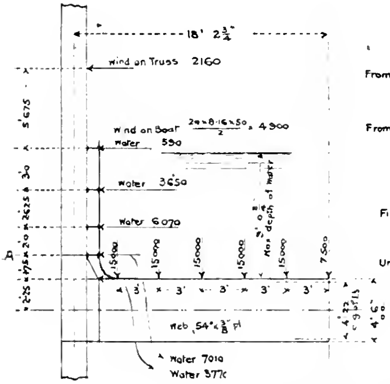
The sand and gravel is subjected to very rigid inspection, and none is allowed to be used in which there is an appreciable amount of clay or foreign material. For mortar not to be incorporated into concrete the sand is kept separate, but for concrete purposes the sand and gravel is mixed, and an effort is made to get the sand and gravel uniformly graded from the size which would ordinarily be called sharp sand up to gravel stones an inch and a half in diameter.

About two-thirds of the concrete already in place has been mixed by a "continuous" mixer, which is a long box of square section, open at both ends, set on an incline and caused to rotate. The ingredients of the concrete are fed into a hopper at the upper end, water is forced into the upper end of the box from a hose held at the lower end, and the materials by the time they reach the lower end of the box are pretty well incorporated. With care an excellent concrete can in this way be produced. The remainder of the concrete has been made with a "cubical" mixer, being a cubical steel box pivoted with one of its long diagonals horizontal. The box is charged with the required proportions of material, the lid closed and the box rotated. When the materials have become sufficiently incorporated, which can best be determined from experiment, the rotation is stopped and the contents discharged. This mixer has an advantage over the continuous one above described that the material may be manipulated as long as it may be considered necessary, and one is quite aware of the amount of mixing in a batch of concrete; whereas with the continuous, it is impossible to tell just where one batch ends and another starts. This in many cases is a disadvantage and requires most careful watching, particularly when it is desired to use concrete of varied strength to suit the requirements of special parts of the work.

In the substructure the proportion of the ingredients is varied according to the importance of the parts. For example, in the towers the batches were made by adding an additional bag of cement, making in this manner a stronger mortar, but using about the same amount of stone as in ordinary work. The mixture of ordinary concrete is given by the specification as follows:—To each cubic yard of approved broken stone there shall be added half a cubic yard of

Stress and Material Sheet

for Floor Beams



Moment at "A"

From Water Pressure — $590 \times 7.625 = 4{,}500$; $3650 \times 4.625 = 16{,}800$; $6{,}070 \times 2 = 12{,}140$ } 33,440

From Wind Pressure — $4{,}900 \times 7.625 = 37{,}400$; $2{,}160 \times 13.3 = 28{,}800$ } 66,200

Fibre stress in Post,

4 – 6×3½×⅜ L's + 21×⅜ pl = 21.56 □" M. R. = 151

Fibre stress from bending — Water, $\frac{33400\times12}{151}$ = 2650

Wind, $\frac{66200\times12}{151}$ = 5250

Unit stress from direct compression = $\frac{119{,}000}{21.56}$ = 5,520

13,420 # per □"

Stress in Floor Beam.

Stress in top flange, + from bending due to vert. loads $\{(15000\times5.5\times18.25)-(15000\times5\times9)\}\frac{1}{4.22}$ = 197,000

– from bending due to hor. loads = $\{(590\times11.625)+(3650\times8.625)+(6070\times6)+(7010\times4)+(3770\times2.25)\}\frac{1}{4.22}+\frac{21100}{2}$ = 36,950

160,050 @ 14000 = 11.42 □"

2 – 6"×6"×½" L's = 11.5 □" gross.

Stress in bottom flange, – from bending due to vert. loads = 197,000

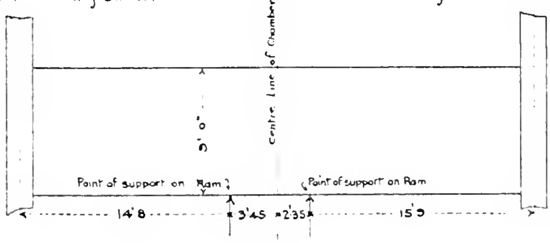
+ from bending due to hor. loads = $\frac{111300}{4.22}-\frac{21100}{2}$ = 15,850

181,150 @ 14000 = 12.92 □"

2 – 6"×6"×⅝" L's = 12.91 □" net

A Typical Intermediate Floor Beam.

Centre Loading Girder. Loading Girder farthest from Centre.



Truss Load 362,500 #, Stringer React.ⁿ 4,150, (Girder (say) 25,000 pounds) Truss load 362,500, Stringer React.ⁿ 9350.

Moment over support
$(362{,}500\times14.8)+(4150\times28.2)+(10{,}000\times5.5)$ = 5,534,400

Flange stress, $\frac{5{,}534{,}400}{9}$ = 615,000 @ 14000 = 43.8 □" req'd.

2 – 6"×6"×¾" L's & 3 – 18"×⅝" pls. = 43.88 □" net.

Shear, 383,000 #, 108"×$\frac{9}{16}$" web = 60.75 □" = 6,400 # per □"

Moment over support
$(362{,}500\times15.9)+(9350\times33.25)+(12{,}500\times7)$ = 6,161,500

Flange stress, $\frac{6{,}161{,}500}{9}$ = 684,600 @ 14000 = 48.9 □"

2 – 6×6×¾" L's, 2 – 18"×¾" pls, & 1 – 18"×$\frac{11}{16}$" pl = 48.88 □" net

Shear, 420,000, 108"×$\frac{9}{16}$" web = 60.75 □" = 6900 # per □"

Central Loading Girders

screened gravel, one quarter of a cubic yard of sand and three and one-half cubic feet of Portland cement.

This mixture will not work in these rigid proportions in all cases,—the kind of cement, the fineness of the sand and the gravel and the product of the stone crushers all having an influence. The idea is to have a rich mortar which will bind the coarse materials together, the varying sizes of the gravel and of the broken stone giving uniformity of density to the mass. It has always been found necessary to separate the different parts for trial mixtures, and in these the stone and gravel is added to "fill."

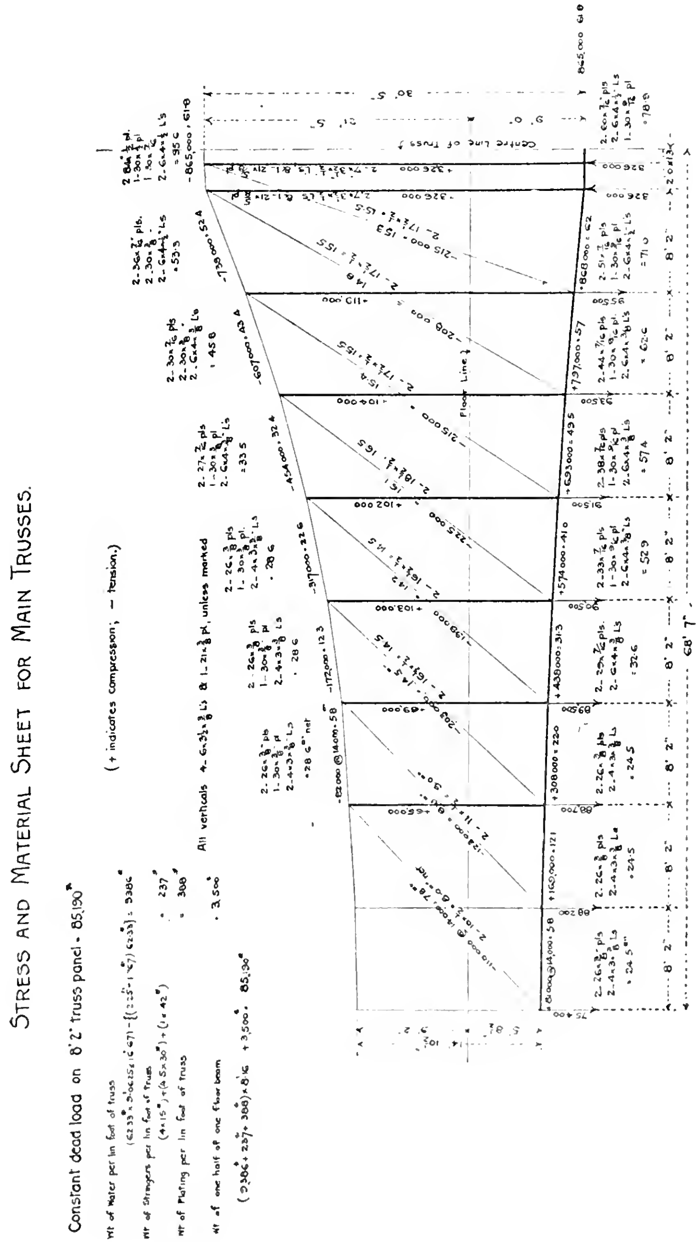
All of the concrete is made and placed under careful inspection and the component parts are watched to see that no changes in the conditions occur.

On all the exposed faces of the work, mortar (generally 1 cement to $2\frac{1}{2}$ or 3 of sand) to a depth of about three inches is placed. This mortar is mixed at the same time as the remainder of the concrete, and is deposited simultaneously, usually by one man with a shovel, who does nothing else but attend to this matter, keep the moulds clean, and see that none of the coarser material of the concrete is allowed to touch the forming which retains the concrete in position until settling has taken place.

The forming or moulding throughout is made of pine lumber, three inches in thickness and about ten inches wide. The face side of the timber is dressed to a smooth surface and the edges of the planks are rabbeted so as to form a lap joint. The studding to support this surface is required by the specifications to be 6″ x 8″ stuff set up at about 4 foot centres. It has been found absolutely necessary to use stiff forming like the above in order to preserve uniform lines on the face of important walls. Back lines of the walls are constructed by rough inch boarding which oftentimes does not present a very workmanlike appearance as far as the carpentry is concerned, but so long as the lines are kept reasonably near what is intended nothing more is required in this particular.

THE SUPERSTRUCTURE.

The superstructure of the hydraulic lock, which is under contract with the Dominion Bridge Company of Montreal, was let in the spring of 1898. Some slight modifications in the plans,


Stress and Material Sheet for Main Trusses.
Constant dead load on 8' 2" truss panel = 85,190#
(+ indicates compression; − tension.)
All verticals 4 - 6 x 3½ x ⅜ Ls & 1. 21 x ⅜ pl, unless marked
Centre Line of Truss
Floor Line
68' 7"

however, have been made from time to time as a more complete and careful study showed that this could be done to advantage; but in the main details the contract plans have been rigidly adhered to. For purposes of description it would perhaps be well to separate the construction into its different important parts,—the lock-chambers, the guides, the gates and their operating machinery, and the auxiliary mechanical plant.

THE LOCK CHAMBERS.

As has already been mentioned, the lock chambers of this lock are very much larger than those of any lock previously built, having a width practically double that of the largest of the others. The clear inside dimensions of each of the chambers are 139 feet long and 33 feet wide, with a free board of 9 feet 10 inches. These dimensions, with the exception of the depth of water, are fixed by Government commission; and it is necessary, as well as complying with the conditions above, that a clear headway of 25 feet be left above the water-level. (It would appear that these sizes were determined upon from the construction of the old form of side wheelers in common use on the Trent waters some years ago.) The depth of water for which the lock is constructed would be called in ordinary navigation language "8 feet on the sills," and the whole of the construction of the canal at the present time is being carried on with a view to using this depth of water, although 6 feet is the nominal depth of the canal. The load of water which each of the lock chambers will contain is about 1,700 tons, and this is the maximum load which it is necessary to provide for, since when a vessel is floating in the chamber it is merely a question of displacement. The trusses which carry the load of the chamber are double cantilevers. The form of these girders has been changed from that shown on the drawings by making the chords parabolic in form, in order to obtain a horizontal platform at the ends next to the reaches. The depth of the trusses at the centre is 32 feet, this depth having been chosen with a view to preventing the teetering tendency, which is always present, rather than that of lowering the stresses due to the water load. The trusses are simple, and it is not necessary in any of the members to provide for alternate stresses, as the load is constant and always in the same direction. All the connections are riveted and stiff; the top chord cover-plate is 30 inches in width,

the diagonals are of flat rolled bars throughout. The stresses with the material are given on the drawing on page 137. The floor beams and stringers extend under the whole of the plating and will form a very stiff frame-work for it. No lateral bracing has been provided, as it is considered that the plating itself will be quite sufficient to withstand any wind stresses. The plating of the chambers is, in the lower part, 3-8 of an inch thick, steel, with 5-16 along the sides. The plates are arranged of such a width that there will be very little fouling of the stringers and floor beams, and they are joined by butt splice plates $4\frac{1}{2}$ inches wide throughout. The riveting of the plating is put in in the same way as for boiler work, and all the edges of the splice plates are caulked by the concave method. The whole of the load of the chambers is, as will be seen, brought directly on to the top of the rams by plate girders 9 feet in depth. There are four of these girders, each taking practically an equal share of the load, as will be seen by an examination of the double system of the trusses.

THE GUIDES.

The guides, which will be required to overcome the teetering tendency which is always present, and to overcome also the tendency of rotation due to the unbalanced wind forces, are placed at the centre of the trusses at the sides and the upstream end. The central guides, which have mainly to overcome the teetering, are placed on the line of the top and the bottom chords and connect with the towers. The guide adjacent to the side tower is made of such a form as to withstand a side pressure of the wind, from which ever way it may be blowing, in this way relieving the centre tower of this kind of load and giving it all to the side one. It will be seen by the masonry drawings that the side tower is of much greater width than the centre one, which is only 12 feet in this direction. Those guides which will probably be the more efficient in overcoming the rotating tendency of the wind are placed at the upstream ends of the trusses and work against steel beams embedded in the concrete work.

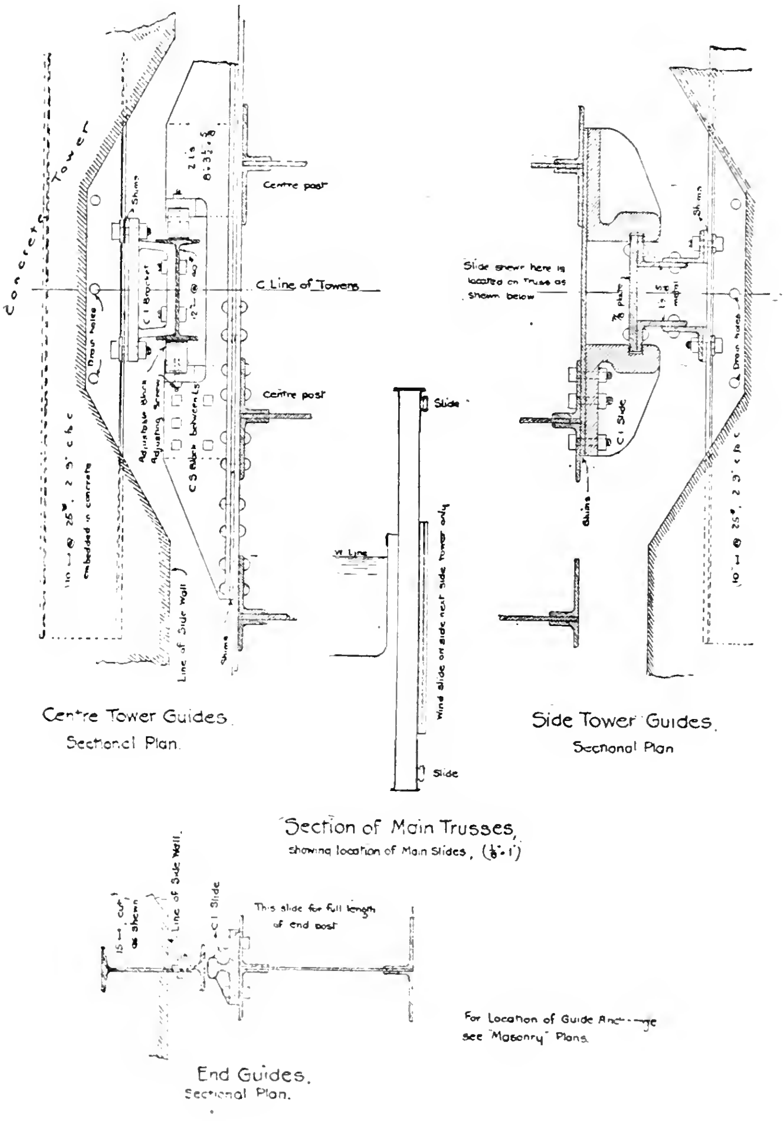
These guides have, in former locks, also to overcome the unbalanced end pressure of the water when the adjacent gates are opened ready for the chamber to receive the vessel. This end pressure has been so small, compared to what is found in the Canadian

lock, that no extra precautions were necessary to care for it. The unbalanced pressure, however, in the Canadian lock is so great that it has been considered advisable to provide a separate means for overcoming this end thrust. The unbalanced pressure produced in this way is 180,000 lbs. and is taken care of by a special "end thrust arrangement" which engages directly with the concrete work. It consists of a steel casting secured to the trusses of the chamber at about the level of the floor line, and these castings engage with others which are firmly anchored to heavy steel beams imbedded in the concrete work.

THE GATES.

The gates and operating machinery are of a very different type from anything that has hitherto been employed for this purpose. The design of the gates is thought to be entirely new. In the European locks it has been the custom to hang and raise them vertically, which has proved to be quite a satisfactory method where the headroom required has not been much more than 8 feet above the surface of the water. However, as it is necessary that 25 feet clear headway be preserved in our case, and as our gates are of necessity about twice the length of the European ones, it did not seem a desirable thing to operate them in the old manner. The method which has been adopted and on which the gates are now being constructed, is clearly seen in the diagram on plan 3, and further in the sketch on page 143.

It will be seen by inspection of one of the gates closing the end of the reach, that it is hinged along the length of its lower edge and arranged so that it will fall flat above the bottom of the gate recesses. As it is never necessary that one of these gates be opened without the other, they are arranged to operate in pairs. The reach gate is controlled directly by a small three-cylinder hydraulic engine and the chamber gate is automatically connected with it. The gates themselves are of steel throughout, the frame work consisting of a series of vertical posts made of I-beams, which connect to the top girder, giving a perfectly determinate system of stresses throughout, and bringing definite abutment loads where they can be readily taken care of. The plating is all on the outer (that is, away from the reach) side of the gate, is 5-16 inches thick on the upper parts, 3-8 inches thick below, is butt-spliced and caulked in



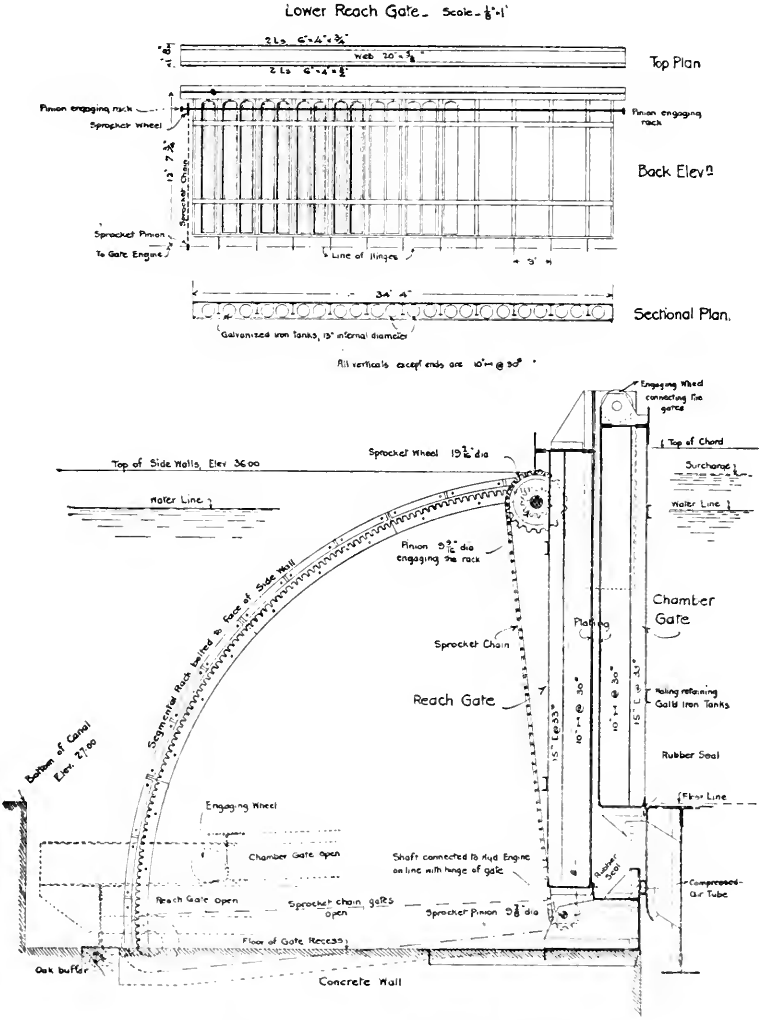
DETAILS OF GUIDES

Scale _ 1"-1

the same manner as the plating of the chambers. In order to render the gates less cumbersome in handling, or rather to make it practicable to handle them, the space between the vertical beams will be taken up by light, water-tight, galvanized-iron boilers of the type commercially known as range or hot-water boilers, and the buoyancy which will be gained by the use of these boilers will make the gate so that it can be readily maintained in any desired position. It was originally intended that this buoyancy should be obtained, as will be seen by an examination of the contract drawings, by plating the gates on both sides and having them caulked. But a further study of the subject seemed to show that this was an undesirable method, as the possible racking of the gates in operation might cause the caulking to become loose, and thus destroy the buoyancy in such a way that it could not easily be repaired; and further the extra amount of plating required to obtain the buoyancy added materially to the weight of the gates. A new method was therefore sought for, and the ranger boiler idea seemed to possess so many merits that it was readily agreed to by the contractors. These boilers are light in construction, thoroughly galvanized within and without, and tested under any required reasonable pressure; and they are cheap. Damage to one or more of them would not materially effect the operation of the gate, and a broken one may be readily replaced at a convenient time. The galvanizing will of course prevent any corrosion of the iron by the water.

Water-tightness is ensured within the gates and chambers, or reaches, by means of a rubber strip, about 3″ x ½″, fastened along the sides and bottom of the frame against which the gate closes. The pressure of the water itself keeps the strip tightly pressed against the gate, in this way preventing any leakage. The edge against which the rubber bears is machined to a true surface.

The hydraulic engine operating the gates is situated in such a way that its main shaft is on a line with the axis of the gate, and a sprocket pinion is attached to it next to the side of the recesses. A second sprocket, which is connected to the former one by a chain, is attached near the top of the gate rigidly to the same shaft as a pinion which engages with a segmental rack fixed to the side of the masonry. The rotation of the engine shaft causes the gate to be raised or lowered. The shaft extends across the top of the gate, and at its farther end has a similar pinion engaging in a corresponding



Section thro' Lower Gates, (Galvanized Tanks not shown). Scale $\frac{3}{8}$"=1

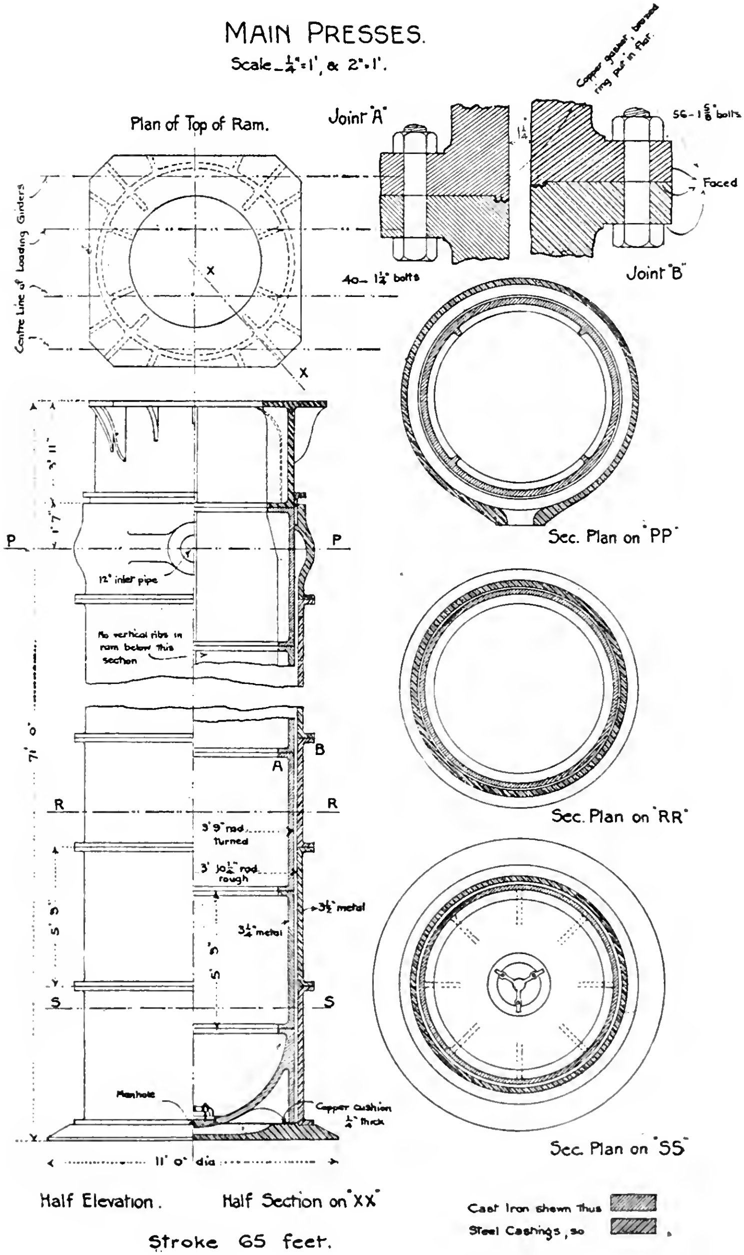
DETAILS OF GATES.

rack, in this way bringing both ends of the gate up without a twisting motion.

While speaking of the gates it would perhaps be well to describe the method whereby a water-tight joint is made between the end of the chamber and the corresponding end of the reach. The end of the chamber clears the end of the reach by a space of about $1\frac{3}{4}$ inches, and it will be seen that this space has in some manner to be closed before the water in the canal can connect with that in the chamber, or, in other words, before the gates can be opened. The joint is made by the inflation with compressed air of a rubber tube, which is fastened to the face of the reach along the bottom and up the sides of it. This hose is made flat in form and lies against the frame of the gate. When inflated with air, at a pressure of about 27 pounds per square inch, it will form by its tendency to become circular, a joint which will be perfectly water-tight under a head of 12 or 14 feet, which is the maximum depth of the water at this place. In practice it is intended to inflate this hose only as much as may be necessary to make the joint tight, because the intended amount of pressure increases materially the "end thrust" which is referred to when speaking of the guides. At one of the European lifts this joint has been made by building the end of the lock chamber on a taper and having a movable wedge, faced on both sides with rubber, so adjusted against the end of the reach that when the chamber comes to the top of its stroke, the two inclined faces would bind against one another and in this way form a water-tight joint. This method, while it has its advantages, seems also to have its disadvantages, and these were considered so great that the hose idea was adopted.

THE LARGE PRESSES.

The presses, which are really the most important part of the whole mechanism, differ very materially from anything that has hitherto been constructed. The pressure by the gauge during operations will be 600 pounds. The rams have a finished, external diameter of 90 inches, and the inside diameter of the presses is 7 feet $8\frac{1}{2}$ inches, giving a clear space of $1\frac{1}{4}$ inches all round the ram. The rams themselves are built of cast iron $3\frac{1}{4}$ inches in thickness, made up in sections. Each section is 5 feet 3 inches long and is bolted to the adjacent ones by $1\frac{1}{4}$ bolts through inside flanges. The


MAIN PRESSES.
Scale $\frac{1}{4}$"=1', & 2"=1'.
Plan of Top of Ram.
Centre Line of Loading Girders
Joint "A"
Joint "B"
40 – $1\frac{1}{4}$" bolts
56 – $1\frac{5}{8}$" bolts
Faced
Copper gasket, brazed ring put in flat
Sec. Plan on "PP"
Sec. Plan on "RR"
Sec. Plan on "SS"
12" inlet pipe
No vertical ribs in ram below this section
3' 9" rad. turned
3' $10\frac{1}{2}$" rad. rough
$3\frac{1}{2}$" metal
$3\frac{1}{4}$" metal
Manhole
Copper cushion $\frac{1}{4}$" thick
71' 0"
5' 5"
11' 0" dia
Half Elevation.
Half Section on "XX"
Stroke 65 feet.
Cast Iron shewn thus
Steel Castings, so

joints between the sections are made perfectly tight by means of a gasket of thin soft copper, rolled true to gauge, of cross section dimensions of $\frac{3}{4}$ inch by 1-16 of an inch. This gasket is brazed in the form of a ring. The end sections of the ram castings are rabbeted to fit into one another and have male and female corrugations. The copper is put in flat and when the joint is screwed down tightly becomes corrugated, making the joint perfectly tight.

It is, however, in the presses themselves that the important changes have been made. In the presses at Anderton, cast iron sections were used throughout. Failure in these caused Mr. Clark to change his plans. In order to obtain a more satisfactory type of press, cast iron at such high pressure being unreliable in tension, many experiments were tried, and the presses at La Louviere and Les Fontinettes were built on two different plans. The Les Fontinettes presses consist of steel hoops, rabbeted and piled on top of one another to make up the required height, water-tightness being gained by an interior lining of copper brazed, in much the same manner as the inner tube of a bicycle tire gives air-tightness to the tire; the copper is water-tight and the steel hoops take all the tension. At La Louviere a different method was tried. The sections of the presses were of cast iron to get the water-tightness, and the strength was given to these sections by means of steel hoops rolled in the ordinary tire mills, rabbeted so as to fit together, heated and shrunk on to the sections. On either end of the cast iron sections a small lip or projection was left while turning them, to serve as a protection against the hoops being dragged off, but these lips were not so large as to prevent the heated hoops from being passed over them. The end hoops of the sections were flanged and served as a means of bolting the adjacent sections together. This has proved to be a very satisfactory type of press, but it requires not very much consideration to see that it is also a very expensive one. The cast iron sections must be turned with the utmost accuracy; the greatest care must also be used to have the hoops bored out, and an immense amount of machining is required on each of the hoops. The heating of the hoops is also a serious matter, and after the press is finished, while there may be no doubt whatever of its suitability, still the actual stresses are very uncertain. They endeavoured to set up sufficient compression in the cast iron when in the normal condition to exactly balance the tension produced by the load when working, and

in this way leave the cast iron in a neutral state of stress. This style was shown on the plans for the letting of the superstructure, and was tendered on by the European firm which built the La Louviere lift, who asked to have them made the same diameter as those at La Louviere (namely, 2 meters) instead of 7 feet 6 inches diameter as our specification required. The present contractors, however, in their tender, submitted also an alternative tender for presses made of steel castings, at the same time making such a substantial decrease in their alternative figure that the Government felt compelled to enquire very carefully into their proposal, with the result that their tender for the presses of steel castings were accepted. Mr. Clark, in his experiments of presses, had tried steel castings, but in one of the large sections he produced failure at about 40 per cent. of its calculated ultimate strength, owing, as examination showed, to the fact that a large piece of scale had become loosened from the mould and had embedded itself in the wall of the casting. This was really all the information along this line that the Government had when entering upon their investigation as to the feasibility of using steel castings for this purpose, with, of course, the knowledge that immense strides have been made in the manufacture of steel castings since the tests at La Louviere were made ten years before. A careful study of the products of some of the large steel casting manufacturers of the United States, and of their test specimens, coupled with the assurance that they were able to make a satisfactory press in this manner, led to the adoption of steel castings, which are now in shape to be placed in the work. The internal diameter, as has been stated, is 7 feet 8½ inches, the thickness of the metal 3½ inches, the length of the sections 5 feet 3 inches, with flanges on either end for connection purposes. The thickness, 3½ inches, was chosen chiefly as a matter of consideration in casting rather than on account of the stresses. The maximum pressure in the presses will probably give a tensile stress in the walls of about 8,500 lbs. per square inch. The Government required that every casting in the presses should undergo a pressure test by water. The maximum pressure to be applied was decided upon as 2,000 lbs. per square inch, which strains the metal of the casting almost up to the elastic limit; and this pressure may be applied and relieved as many times as the engineer may direct. It is considered that this will insure, beyond a doubt, that every casting is perfect

and that no flaws or large faults exist in them. The tests already made on these castings have been eminently satisfactory, and have far exceeded the most sanguine expectations. Not only have the steel castings taken the load perfectly, but there has not been the slightest oozing, while some of the auxiliary ordinary iron castings used in the test have allowed the water to pour through them like sponges.

The tops of the presses are finished with a stuffing box of rectangular form, 1 inch wide and about 10 inches in depth, and will be filled with braided hemp, which before using is about an inch square in section. It is intended to use about nine rings of this hemp in the stuffing box. The hemp is tightened down by means of a steel gland or follower held by stud-bolts tapped into the top section. The gaskets forming a water-tight joint between the adjacent sections of the press, are of copper, the same as those described for the rams. In the tests already performed there has been no difficulty experienced in keeping this hemp packing quite tight under pressure of 1,200 lbs. per square inch.

Another important deviation from former examples is the manner in which the water is admitted to, or discharged from, the presses. It is necessary that a volume of water equal to the volume of one of the rams be forced from one press into the other during the process of lockage. The chief difficulty with the Anderton press was encountered at the point where the connecting pipe joined the presses. To overcome this, a rather complicated inlet system was devised and patented by the Societé Cockerill of Seraing, which has proved very satisfactory on the La Louviere lock. The contractors of the Canadian lock suggested an entirely different form of inlet, which consisted practically in the enlargement of presses at the level of the connecting pipe by a swell, which would permit the water to discharge freely away from the ram. Before approving of this the engineers studied the matter very carefully, and after a most liberal application of hydraulic formulæ, and the most variable results from very slight changes in assumptions, it was decided to perform some experiments to determine if possible what would be the best arrangement of curves for this inlet. A model was made of wood one-fifth full size, and the curves suggested by the contractors were accurately and carefully formed in the model and shellacked. Water from a height of about 30 feet was discharged through this model, which represented as closely as practicable the actual conditions which will

exist, and the curves were correctly and carefully increased, numbers of experiments being performed with each set of curves. It was found that after certain enlargements had been made, that the discharge from the model was no longer effected, and it was assumed from this that these curves would give probably the best results and least friction. These lines were agreed to by the contractors.

The pipe connecting the two presses is 12 inches internal diameter, made of steel castings one inch in thickness, the various lengths being fastened together with bolted flanges. Midway between the presses and immediately under the centre of the central tower is located the main valve, which closes the connection between the presses. This valve is controlled solely by the lock master in his cabin on the top of the central tower. Beside the main gate valve there are two auxiliary valves which are closed or opened automatically by the lock itself during its motion. These valves serve as a protection against possible accident, and each valve is closed by the chamber by the time it reaches the end of its stroke, the closing being started about the last eighth or 8 feet of the stroke.

THE AUXILIARY PLANT.

As has been stated, the hydraulic lock is theoretically automatic, but it will be seen that slight leakages about the gland of the main presses cannot be avoided. For this reason it is necessary that some supply of water under pressure be maintained and always ready when required. This supply is provided from an accumulator.

THE ACCUMULATOR.

The accumulator consists of a cylinder in which a ram works, the ram carrying a weight which may be increased or diminished according as it may be desired to change the pressure in the water contained in the presses. In the accumulator in question it is intended that the ram will be loaded to give a pressure of about 15 lbs. more than that at which the large presses will work, so that in event of additional water being required in either of the large presses, at any time it can be readily admitted from the accumulator. The accumulator receives its supply of water from a pressure pump located in the pump-room, the pump being driven by a small water-wheel working under the head of the upper reach. The accumulator is built after the same manner as the large presses, having a press

or outside cylinder of steel castings. In the type of accumulator invented by Lord Armstrong, the ballast-box, whereby the weight is applied to the top of the ram, is in the form of a ring encircling the press. But this appears to be undesirable, because when the ram is at the top of its stroke there is practically a pivot joint in the middle of the column, the height of which is twice the length of the ram. This accumulator is now built with the ballast-box directly on the top of the ram, and the top of the press is stayed to the walls of the concrete, where it is installed. It is expected that a much steadier motion will be obtained in the machine by this method. The accumulator is installed in a void in the eastern side tower, and a cylindrical well has been carried down to about the level of the top of the large presses in order to contain the press. The stroke of the ram will be accommodated in the height of the tower. The diameter of the ram is 20 inches and its stroke is 30 feet 6 inches. This will give, without further supply from the pumps, a sufficient quantity of water to raise one of the large rams one foot high.

As it was necessary that the accumulator and pump should be installed, it was thought desirable that the gates and the capstans for towing vessels in and out of the chambers might also be operated to advantage from this power, so it was decided to use Brotherhood three-cylinder hydraulic engines to operate the gates, one for each pair of gates upstream and another for each pair of gates down-stream, the gearing being so arranged that only one pair of gates can be worked at a time. The hydraulic capstans are practically of the same form as these engines and are operated by the same power. The engines and the capstans are being constructed by the Hydraulic Engineering Co. of Chester, England.

THE PUMPS.

The accumulator receives its supply of water from two high pressure hydraulic pumps located in the pump-room. Each of the pumps has a capacity sufficient to operate the accumulator, the two being provided in order to form a duplicate plant. The pumps are built in the most substantial manner, having bronze pistons and piston rods, and bronze-lined cylinders. They are directly connected to the turbines by which they are driven, and are so arranged that in case of accident both can be connected to pump up the lock-chambers singly so as not to completely stop the traffic on the canal.

A pump having a capacity of about 20 cubic feet per minute is provided for the continual unwatering of the lock-chamber pits and is placed in the lower gateway engine chamber discharging into the lower reach. It will doubtless be impossible to keep the lock-chamber pits perfectly dry, owing to the height of the water back of the walls. This, together with a certain amount of leakage from the presses and other machines, as well as from the gates, will accumulate in the lower portions of the pits around the main presses. When this water reaches a level very nearly the floor of the pits at this place, this pump will be automatically started and work until the water is taken out to the desired level.

THE TURBINES.

The turbines operating the pressure pumps are located in the pump-room and derive their power from the 65-foot head of the upper reach. This water is taken in through a screen or rack at the side of the reach, and down a vertical penstock leading into the pump-room, the wheels discharging into the two draft tubes embedded in the concrete wall separating the pump-room from the culvert into which they empty. The culvert conveys the water to the level of the lower reach, where it will be utilized to make up for the evaporation and percolation on this short stretch of the canal. Each of the turbines is 16 inches in diameter and is of the "Croker" type. The turbines are built in the most substantial manner and have bronze steps. It is ordinarily intended that one of the turbines shall be utilized to operate one of the pumps, while the other will generate electricity for lighting the lock and for supplying electrical power for any other object which may be deemed advisable within reasonable distance of the lock, such as the operating of the swing bridges and the guard gates. The turbines are arranged so that each can work either pump. The working of one pump is all that will ordinarily be required: if necessary, however, both may be operated at the same time.

THE DYNAMO.

The type of dynamo has not yet been decided upon, but it will be sufficient to provide about 100 arc lamps. It is intended to install this machine in the central chamber of the pump-room, belting it directly to the turbine nearest to it.

THE TAYLOR HYDRAULIC AIR COMPRESSOR.

Reference has already been made to the air tube which forms a joint between the ends of the chambers and the ends of the reaches and which is inflated with compressed air, when it is required to make the joint. This air is supplied by a compressor, built under the patents of the Taylor Hydraulic Air Compressing Co. of Montreal, and is located in the south-west corner of the main well. It receives its supply of water from the upper reach and the air is compressed by becoming entangled with the water at the point of inlet, dragged down by the water to a depth considerably below that at which the water escapes, and afterwards collected below and thence delivered into the pump-room. The inlet of the water indicated on the masonry plans is about 13 feet above the outlet, which may be seen passing over the top of the main wall, and into this the inlet or feed-pipe delivers. The headpiece is a device separately patented whereby air is admitted so as to become entangled with the inflowing water.

It is connected through its base by an 18-inch pipe to a tank 85 feet below it. The connection at the lower end of the pipe is made on the side of the tank where the water is given a horizontal and rotary motion, allowing the air to collect in the conical top of the tank. A 4-inch pipe is attached at the top of the cone, delivering the air at the required destination. The lower tank, 11 feet in diameter, is open at the bottom, permitting the water to escape after the air is released. The water then rises around the outside of the tank and up the 42-inch shaft in which the 18-inch down-pipe, before referred to, is placed, and escapes at the outlet above the level of the top of the roadway. The pressure of the air is that due to the column of water from the water-line in the lower tank to the level at which the water escapes in the outlet at the roadway level. The lower chamber also forms a reservoir for, as well as a collector, of the compressed air; the compressor is automatic in its action and runs continuously, a safety valve being provided to allow the air to escape when too much accumulates below.

From the pump-room the compressed air is led in pipes to the various places at which it is required to be used.

METAL IN THE SUPERSTRUCTURE.

A summary of the amounts and the various kinds of metal included in the superstructure is as follows:—Rolled steel in plates and shapes for the lock-chambers and gates, 1,680,000 lbs.; cast iron in the main rams, accumulator, guides and various machines, 495,000 lbs.; steel castings for the main presses and accumulator, 668,000 lbs.

OPERATION.

The operation of the lock will require three men—a lock-master and two assistants or gatemen. The duties of the lock-master will be to oversee everything, and he will be fully responsible for the structure. The gatemen will be required, one at the lower end and the other at the upper, to open and close the gates, make good the joints between the ends of the chambers and the reaches and to operate the capstans. It will also be necessary for the gatemen to take charge of vessels at a distance of about two hundred feet above or below the lock, at which point the vessels will pass into the sole charge of the hydraulic lock men.

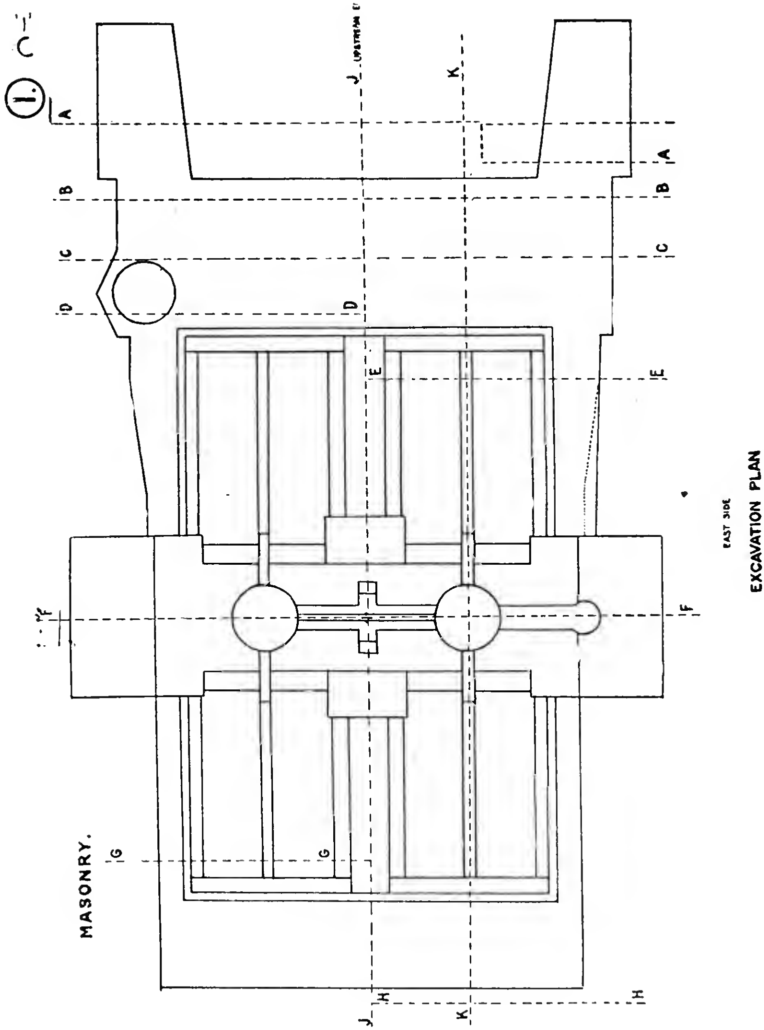
The lock-master, during operations, will be required to stay in his cabin, located on the top of the central tower, where he will be in full view of all the operations and in full communication with both of his assistants by a simple signal system. The lock-master will have all the levers before him, and will control all the workings of the lock. The levers for controlling the gates, water-tight joints, capstans and all parts of the apparatus will be interlocked so that none of them can be moved out of proper order, thus guarding against possible accident and giving the lock-master complete and sure control of the whole apparatus. In order to get a clear idea of the complete mode of operation, let us assume that both lock-chambers are down at the lower level, and empty, as they will be at the end of the winter, or even when it is desired to prepare them for navigation purposes. Each of the presses will be filled with water by the pumps. The main valve on the connecting pipe will be closed and water will be pumped into one of the presses until the ram with its superimposed chamber rises to the level of the upper reach. An examination of the case will show that it is necessary that the uppermost chamber, in order that it shall be able in descending to cause the other to take the full upward stroke, must

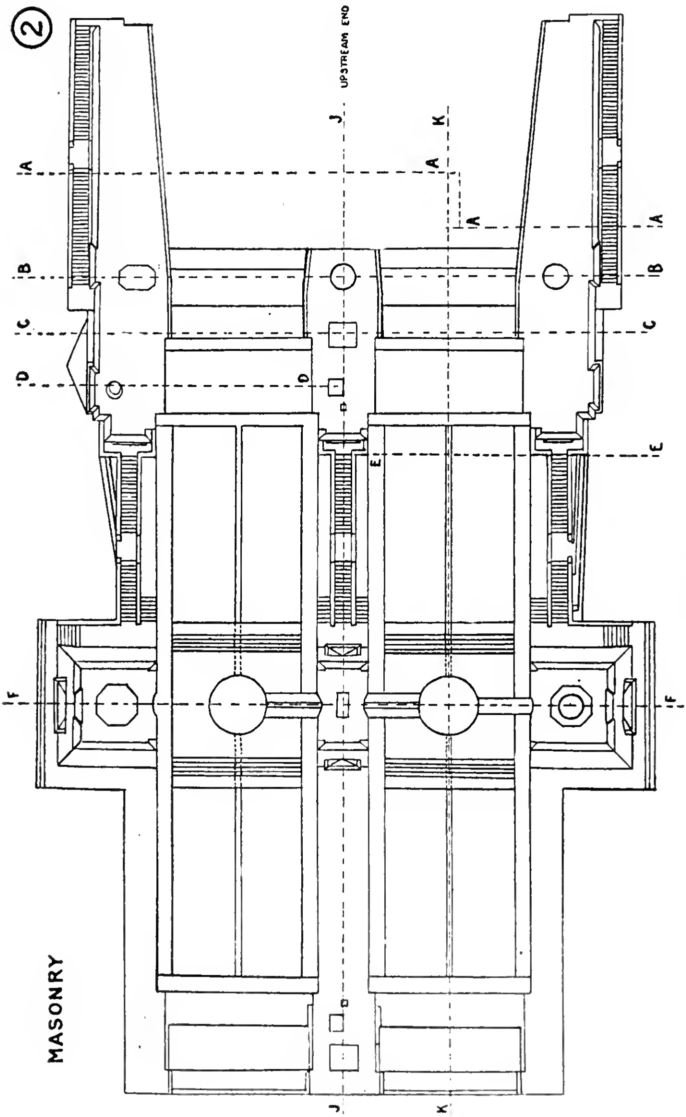
contain a volume of water greater than the rising chamber contains. This extra amount of water is equal to the volume of one of the main rams, since the change that takes place during the relative motion of the two chambers, is that the ram of the descending chamber becomes constantly immersed while the other protrudes. In popular language, the descending chamber is losing weight while the ascending one is constantly becoming heavier. It is also necessary that some extra weight or "surcharge," as it is called, be provided to overcome the friction of the guides and of the stuffing boxes of the main presses. The area of each of the lock-chambers is so great that it requires only an additional depth of $8\frac{1}{4}$ inches to give an extra load of water of 100 tons, which will, no doubt, be quite sufficient. The addition to this weight will, of course, have the effect of accelerating the time of the relative change in position of the chambers. It is intended that the actual time required in raising the chamber through the whole elevation, will be about three minutes. But this will depend upon the adjustment of the main gland, the nicety of the working of the guides and the controlling of the main valve in the hands of the lock-master. In the European locks this part of the lockage is readily performed in three or four minutes. Suppose that the uppermost chamber will be required to stop, say with its floor $8\frac{1}{4}$ inches lower than the bottom of the upper reach. When communication is established between it and the reach it will have a load of 100 tons in excess of that in the lower reach, assuming that the depth of water in the two reaches is the same. Then the total operations to perform the lockage, assuming that the gates adjoining the reaches are open and that the water-tight joint between the chambers and the reaches is made, will consist in hauling the vessel into the chamber and mooring her there securely, closing the gates, deflating the water-tight joint and opening the main valve between the presses. The heavier chamber will commence to descend, the motion being allowed to increase gradually by the gradual opening of the valve, until it reaches the maximum speed. At about three-quarters of the stroke the main valve is slowly closed, communication between the presses being entirely cut off when the end of the journey is reached. Theoretically it would appear possible to have an ideal surcharge which would perform the required stroke without the operation of any valve whatever. The change in elevation being made, the water-tight joints are again made

by the air tubes between the chambers and the adjacent reaches, the gates are opened and the vessel or vessels are free to go on their journey, after being towed out by the capstans. The surcharge contained in the descending chamber simply flows out into the lower reach, while a similar quantity to perform the next lockage is admitted into the chamber which has just reached the higher elevation.

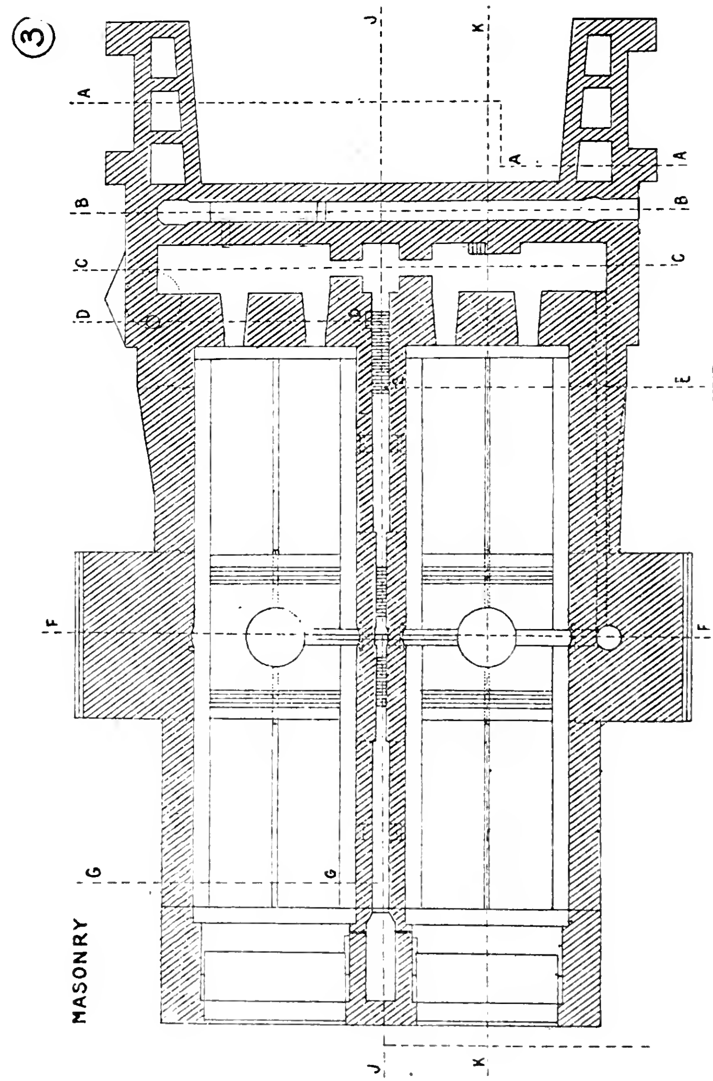
It would appear that the hydraulic lift lock possesses many advantages over locks of the ordinary type. First of all it bears the same relation to the ordinary lock as the double track railway does to the single, for one vessel may be locked downwards and another upwards at the same time, this making no difference whatever to the lockage, as the admission of the vessel is merely a question of displacement of so much water. Again, the saving of time is an important item, for the total operation is readily performed within a space of twelve minutes, while with the ordinary locks an hour or more would be considered fast work. The third advantage, and one which is of great importance where there is a scarcity of water in the upper reach, is the small quantity of water required to make the lockage. In the ordinary form of lock the amount of water is equal in volume to the area of the lock multiplied by the height through which the lift is made, which is very many times greater than the quantity required by the hydraulic lift lock; indeed, certain conditions of traffic may arise which make it possible for water to be delivered from the lower level into the upper.

OUTLINES OF WORKING DRAWINGS OF MASONRY SUB-STRUCTURE OF LOCK.

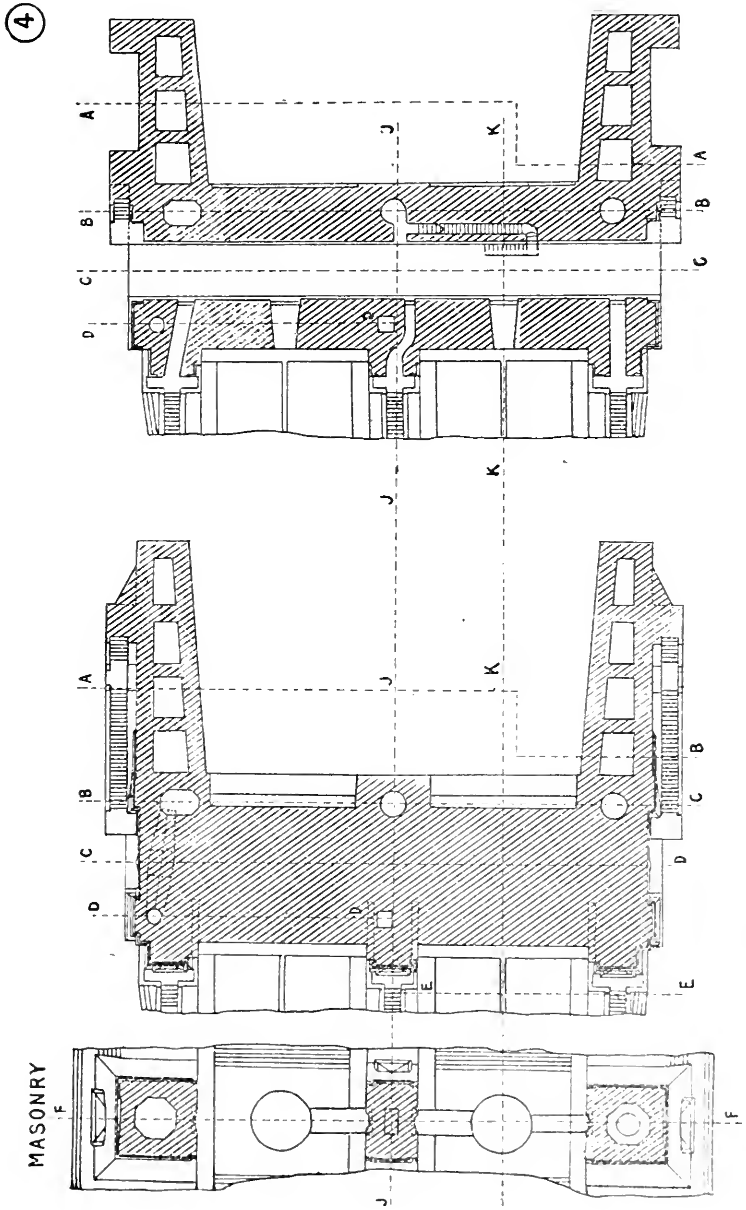


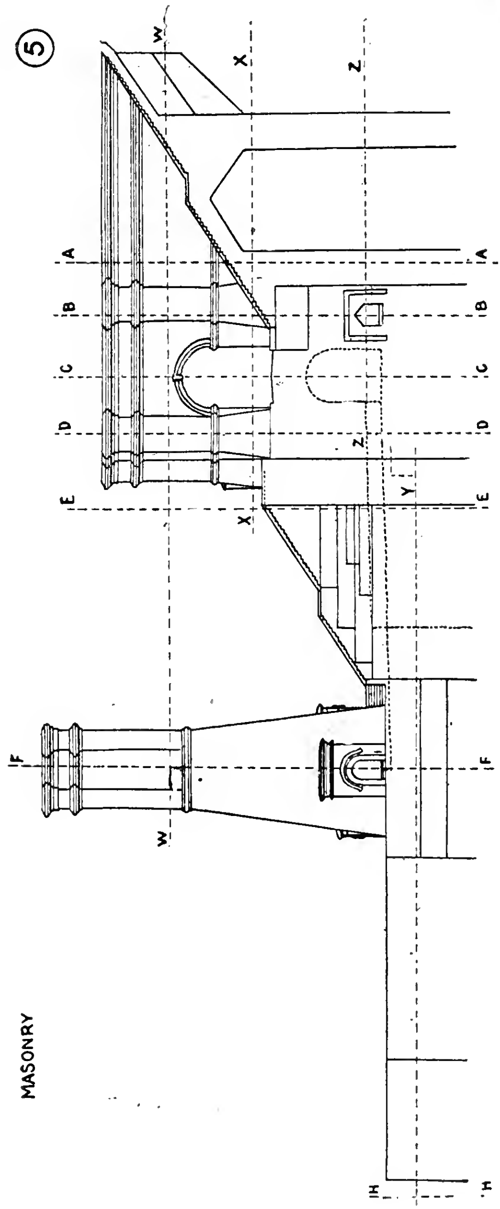


EAST SIDE
TOP PLAN



SECTIONAL PLAN AT 'YYZZ'


4
SECTIONAL PLAN AT 'XX'
SECTIONAL PLAN AT 'WW'
MASONRY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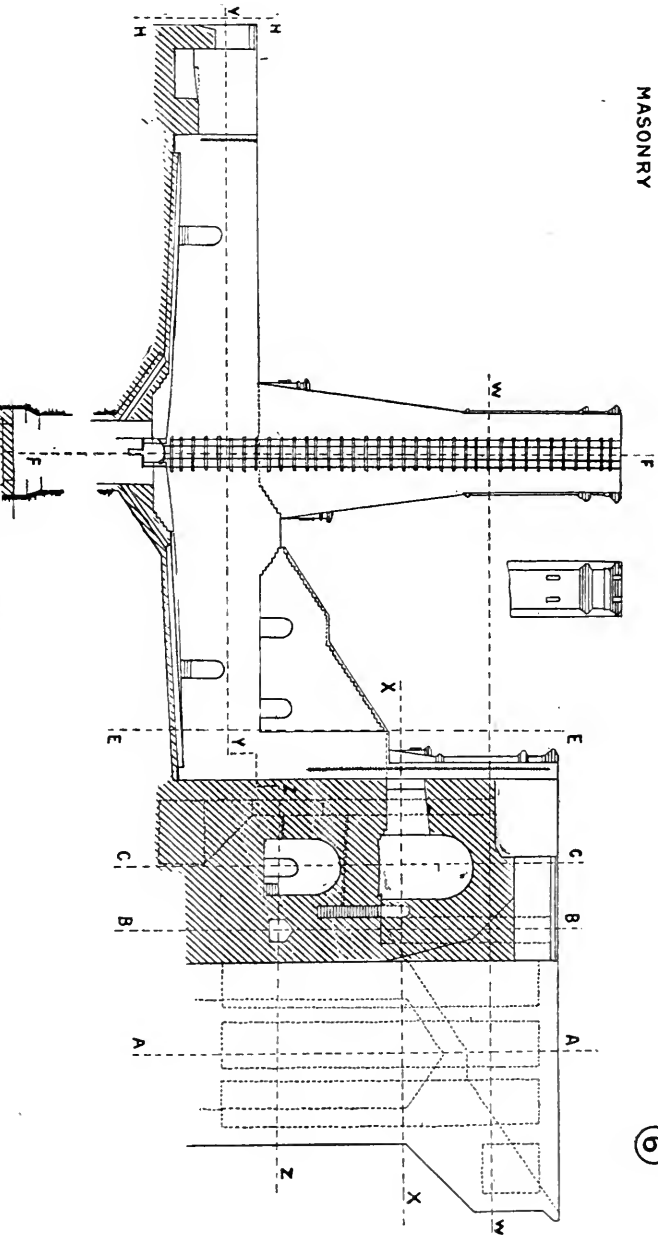
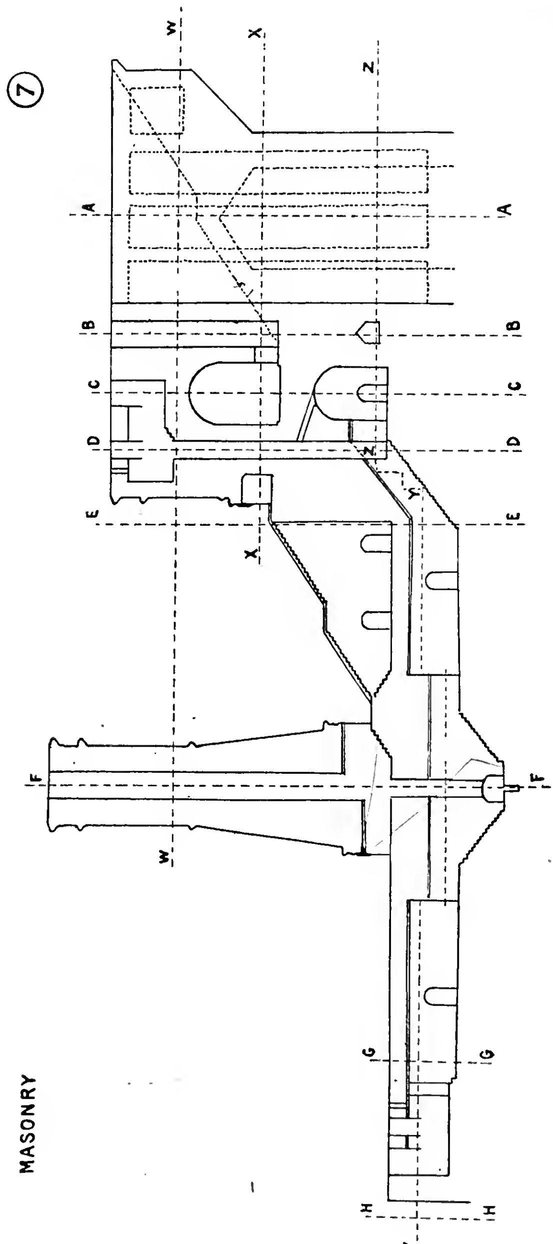
MASONRY



LONGITUDINAL SECTION AT "KK"

6

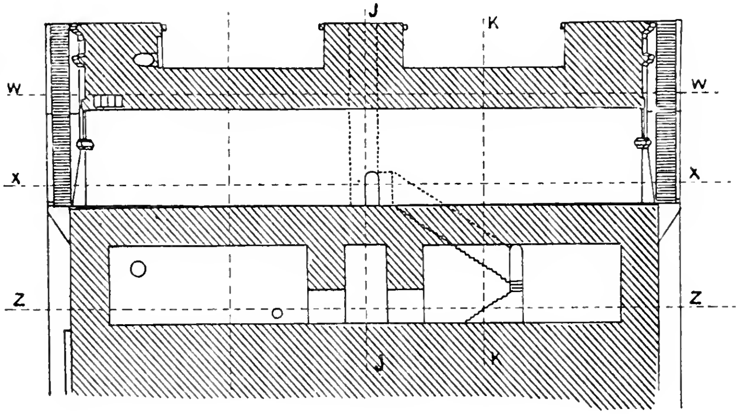


MASONRY

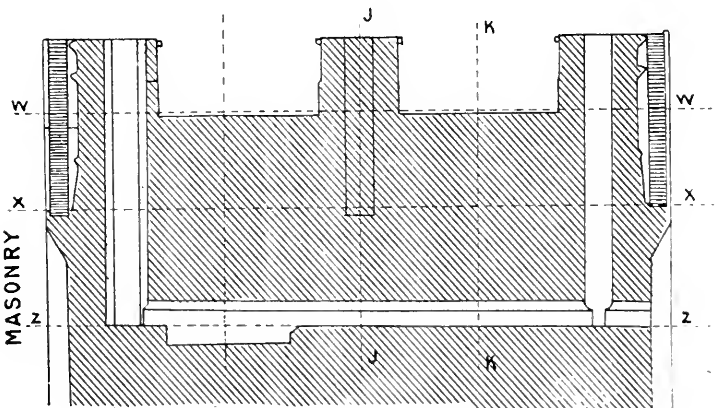
LONGITUDINAL SECTION AT "JJ"

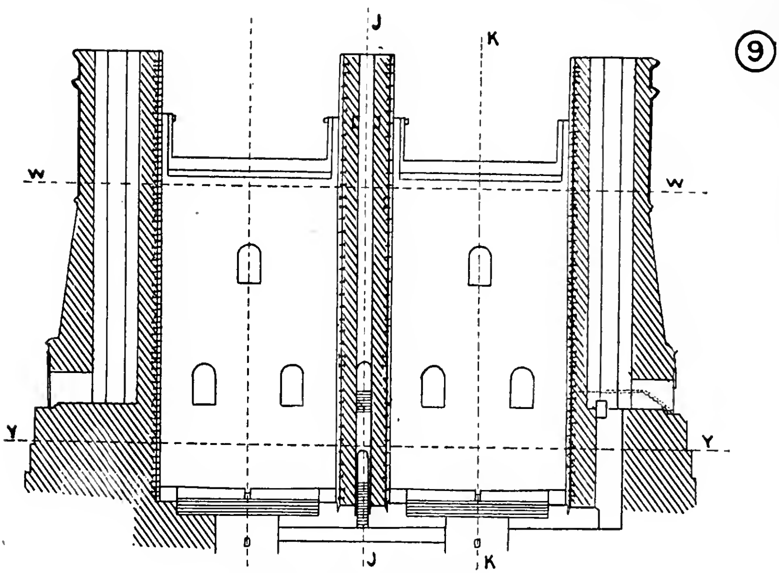
TRANSVERSE SECTION AT "CC".

8



TRANSVERSE SECTION AT "BB"





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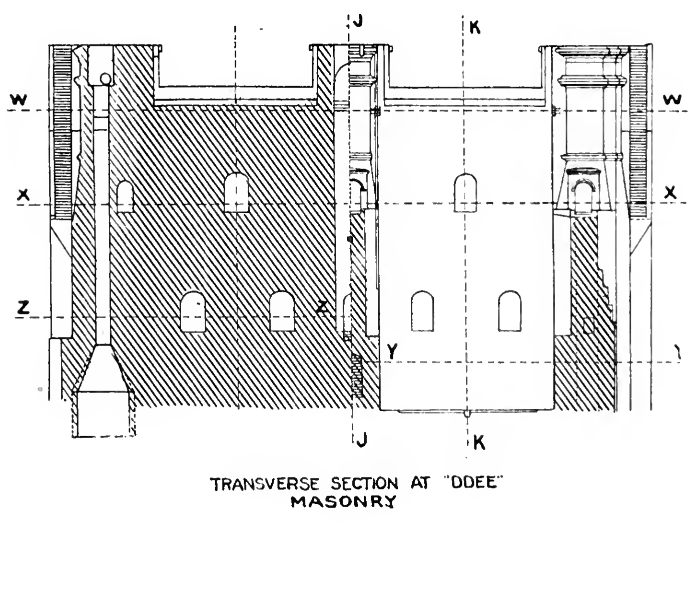
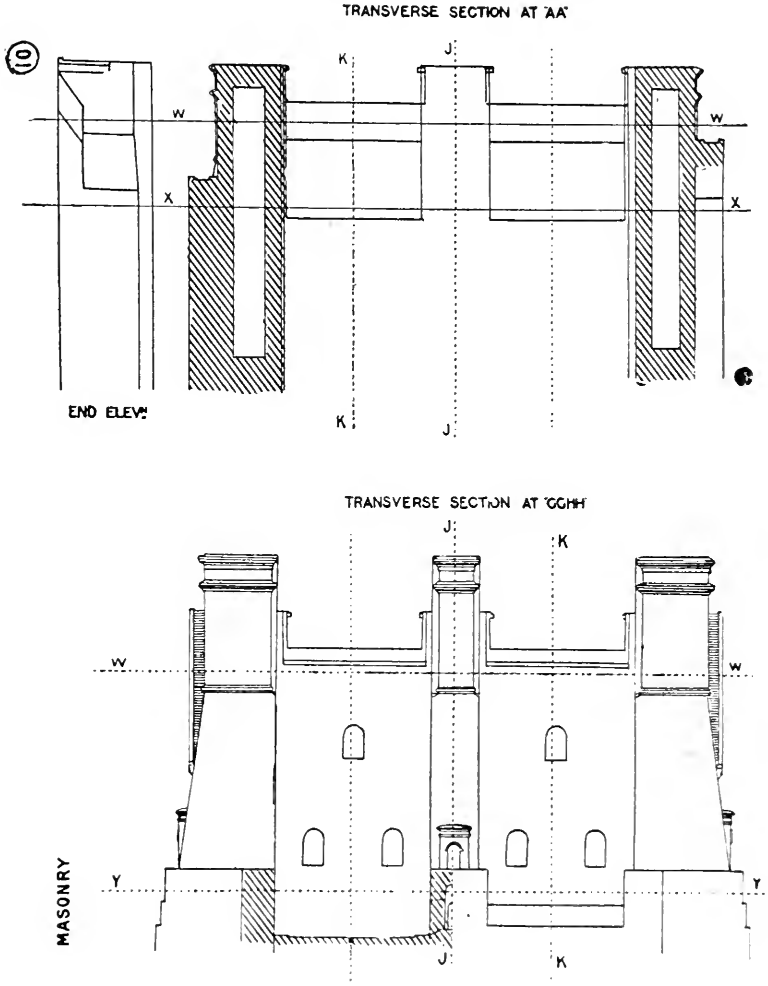


TRANSVERSE SECTION AT "DDEE"
MASONRY


TRANSVERSE SECTION AT 'AA'
10
W
X
K
J
END ELEVN
TRANSVERSE SECTION AT 'GGHH'
MASONRY
Y

REPORT OF THE TREASURER.

Mr. President,—I beg leave to submit the following statement of balances, receipts and expenditures for the period between April 27th, 1901, and March 21st, 1902:

To Balance on hand April 27th, 1901		$ 219 49
To amount from advertisement and sale of pamphlet No. 14	$ 157 73	
" " collected as fees of ordinary members	170 00	
" " received from Librarian	640 95	
" " received as life-members' fees....	16 00	
		984 68
Total		$ 1,204 17

By amount paid for publishing pamphlet No. 14.....	$ 424 00	
" " " postage	11 67	
" " " photos and frames for library	4 50	
" " " printing and stationery.	11 25	
" " " paper, supplies, etc.	546 60	
" " " ribbons, flags, etc.	18 97	
" " " representatives to Queen's and McGill	38 35	
" " " customs and exchange...	2 94	
" " " advertising committee...	3 85	
		1,062 13
By Balance in Bank of Commerce		142 04
		$1,204 17

It might be well to bring to the notice of the members the fact that very few of the graduates pay the necessary fee to entitle them to life membership and our annual pamphlet.

Also that the cost of our pamphlet far exceeds the sum received from our advertisers. If our life members would assist us in this matter we would soon be in a position to make our publications more valuable than they now are. All of which is respectfully submitted.

Yours,

E. A. JAMES,

Treasurer.

AUDITORS' REPORT.

We hereby certify that we have this day examined the accounts of the Treasurer, and vouchers therefor, and find a balance on hand of $142.04.

There is an outstanding debt of $60.49, and outstanding accounts due the Society of $28.00.

R. J. DUNLOP,
F. D. HENDERSON,
Auditors.

March 21st, 1902.

INDEX TO THE FIRST FIFTEEN NUMBERS.